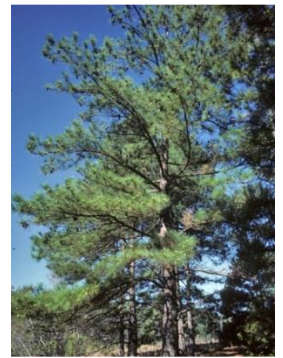


# Mercury contamination in the south central US: Patterns, causes and consequences



**Matt Chumchal and Ray Drenner**  
**Biology Department, Texas Christian University**  
**Fort Worth, Texas**  
**<http://www.bio.tcu.edu/aquaticecologylab/>**

# TCU Aquatic Ecology Lab



**Brad Blackwell, MS 2008**  
**Byron Henderson, MS 2010**  
**Yanci Deng, BS 2010**  
**Christina Jones, MS 2012**  
**Brent Tweedy, MS 2013**  
**Taylor Jones, MS 2013**  
**Meghan Lewis, BS 2013**  
**Holly Whitt, BS 2013**  
**Shannon Speir, BS 2014**  
**Kim Adams, MS 2014**  
**Gretchen Gann, MS 2014**  
**Cleve Powell, MS 2014**

<http://www.bio.tcu.edu/aquaticecologylab/>

# Funding Acknowledgements



- **Texas Christian University  
Research and Creative  
Activities Fund**



- **NextEra Energy Resources**



# Global Mercury Contamination of Aquatic Ecosystems

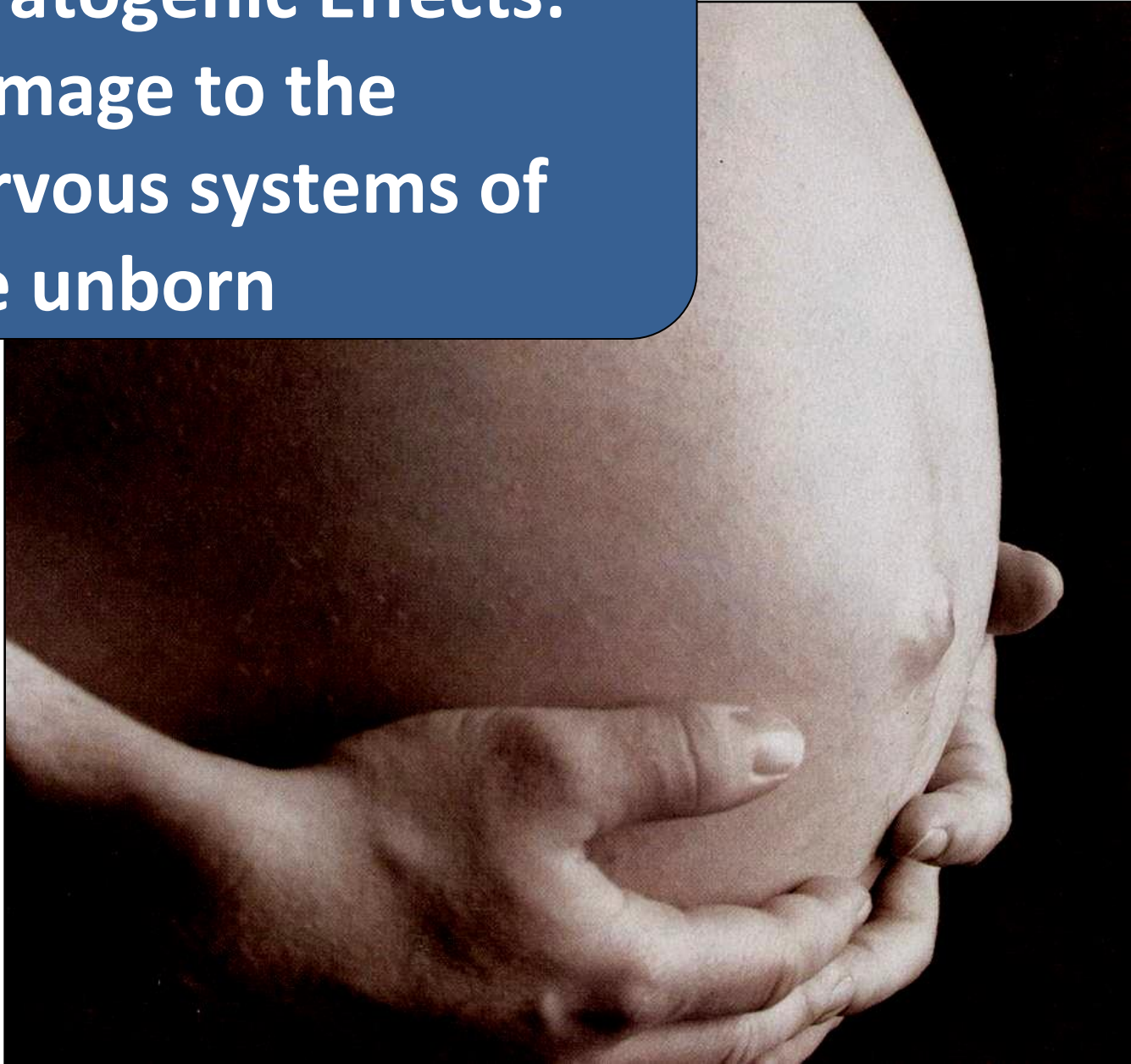




# Reduced reproductive success in fish and birds



# Teratogenic Effects: Damage to the nervous systems of the unborn



# Mercury Cycle

Hg in global atmospheric pool



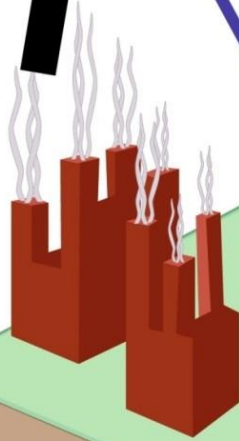
Hg in local atmosphere

Natural sources



Volcano

Anthropogenic sources



Power plants,  
Artisanal gold mining

Hg in Watershed

In aquatic ecosystems,  
IHg converted to MeHg



MeHg  
bioaccumulates  
in food chains



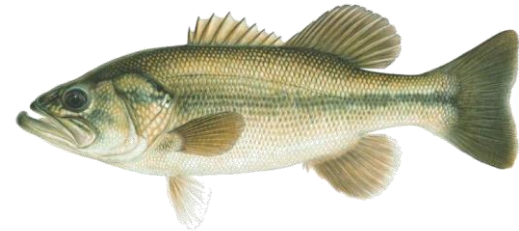
# Biomagnification of Mercury

**MeHg**

**Mercury in fish-eating mammals and reptiles**  
500-1000 ppb



**Mercury in fish-eating fish**  
300 ppb



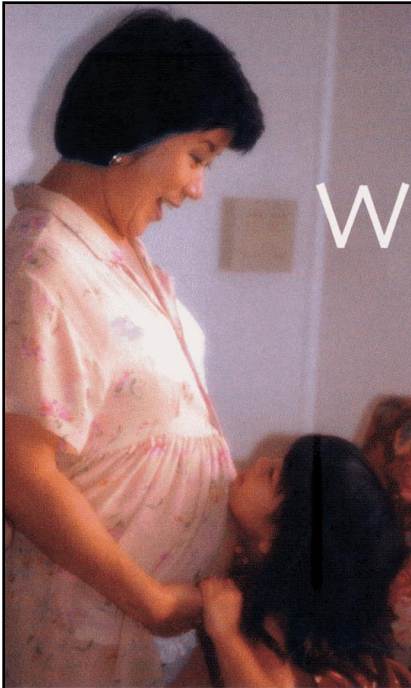
**Mercury in planktivorous fish**  
100 ppb



**Mercury in aquatic invertebrates**  
30 ppb



# Joint Advisory from US FDA and EPA



## What You Need to Know About Mercury in Fish and Shellfish

### *Advice for*

Women Who Might Become Pregnant  
Women Who are Pregnant  
Nursing Mothers  
Young Children

*from the  
U.S. Food and Drug Administration  
U.S. Environmental Protection Agency*

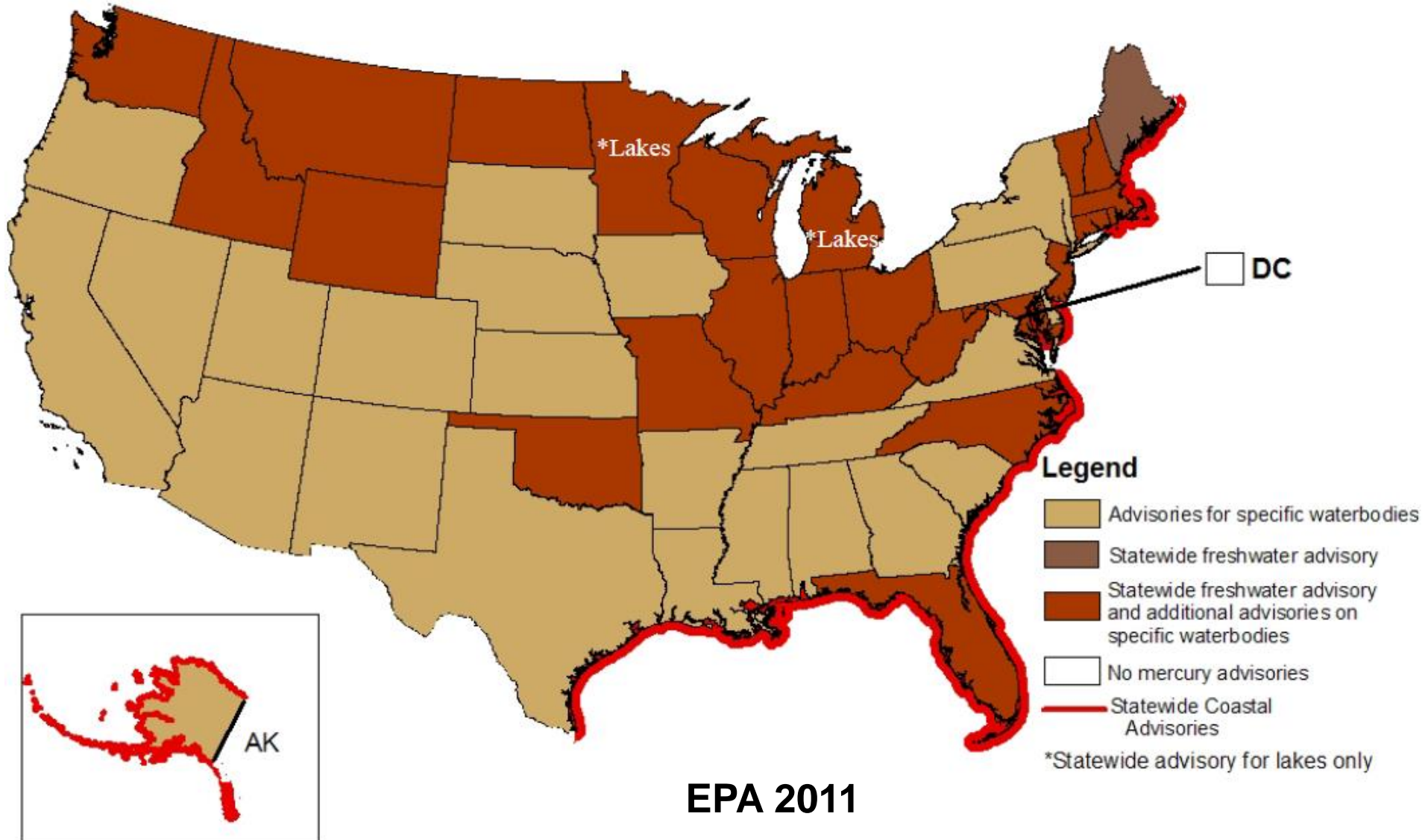
### Mercury (parts per million)\*\*

Tilefish	1.45
Swordfish	1.00
Shark	0.96
King mackerel	0.73
Tuna, fresh and frozen	0.32
Halibut	0.23
Mahi mahi	0.19
Tuna, canned	0.17
Catfish	0.07
Salmon	Not detectable
Tilapia	Not detectable

\*\*Source: DFA

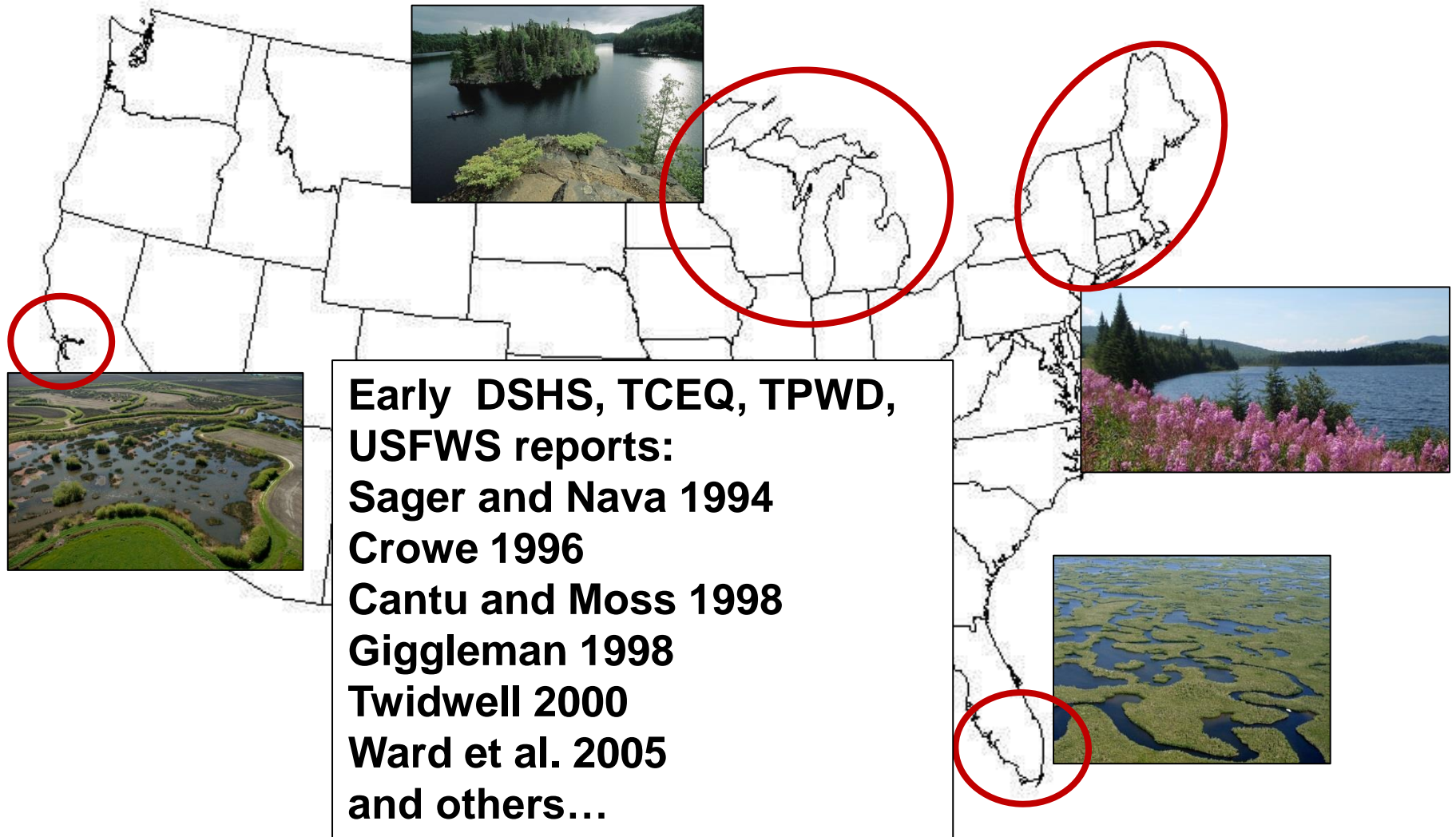
(new advice in Draft form)

# State Issued Fish Advisories

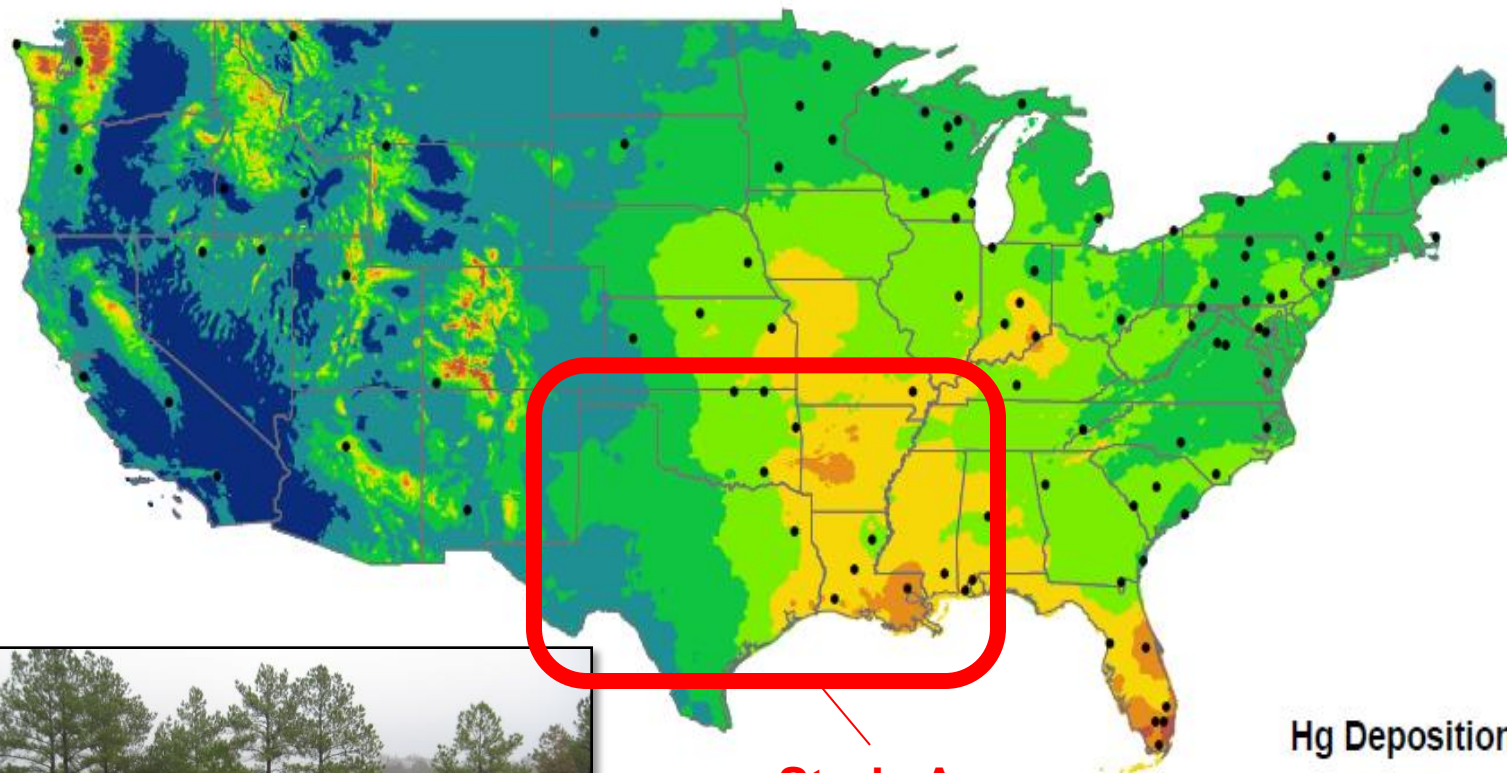




# Areas of Hg Research



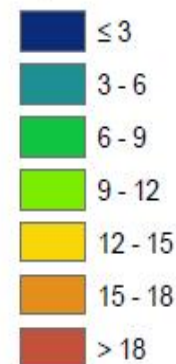
# Wet Mercury Deposition in Open Areas



**Study Area**

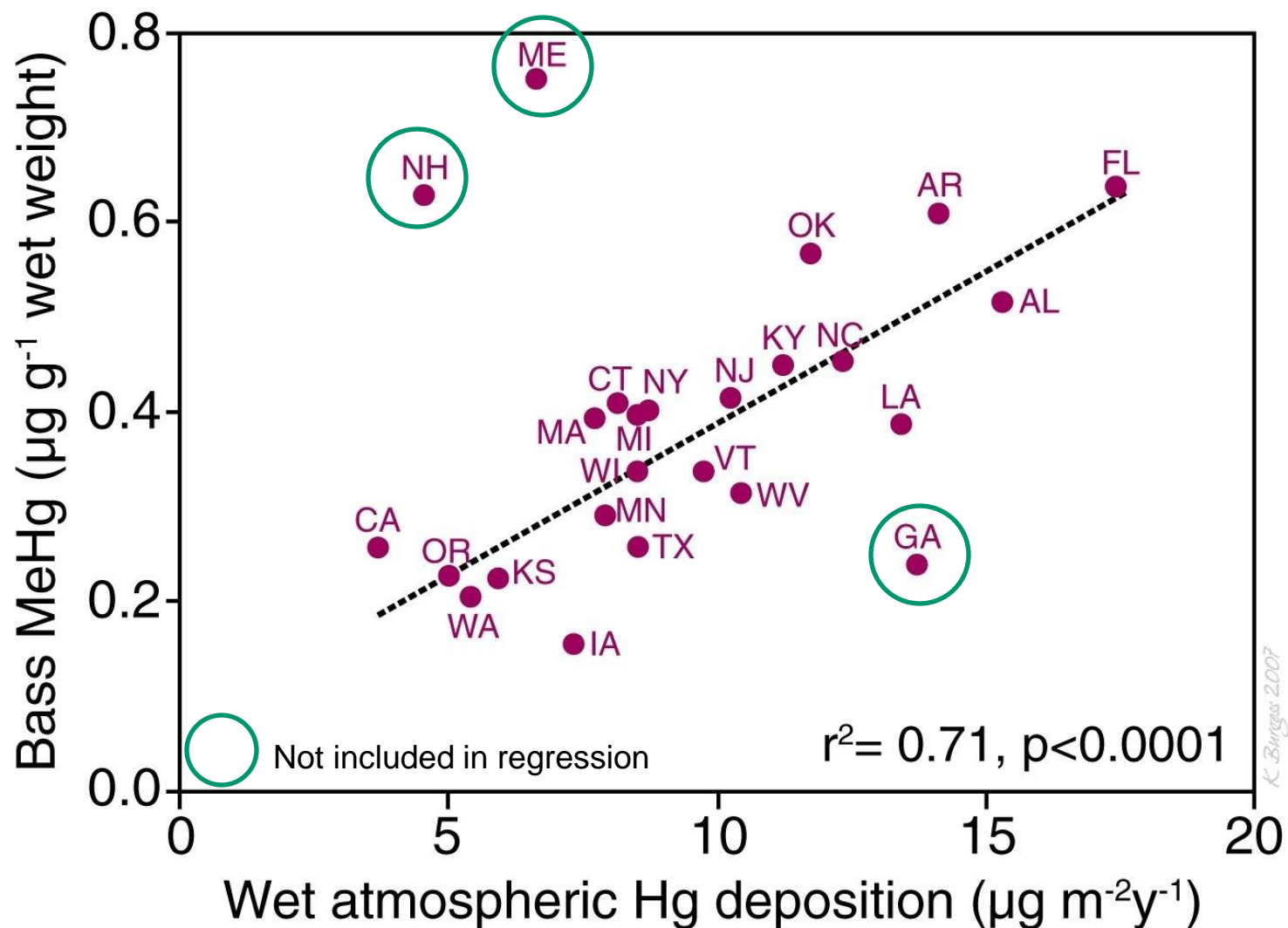
**Data from Mercury  
Deposition  
Network 2006-2009**

Hg Deposition,  $\mu\text{g}/\text{m}^2$



**MDN/NADP Monitoring Location TX 21**

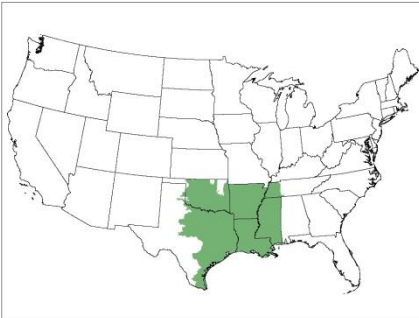
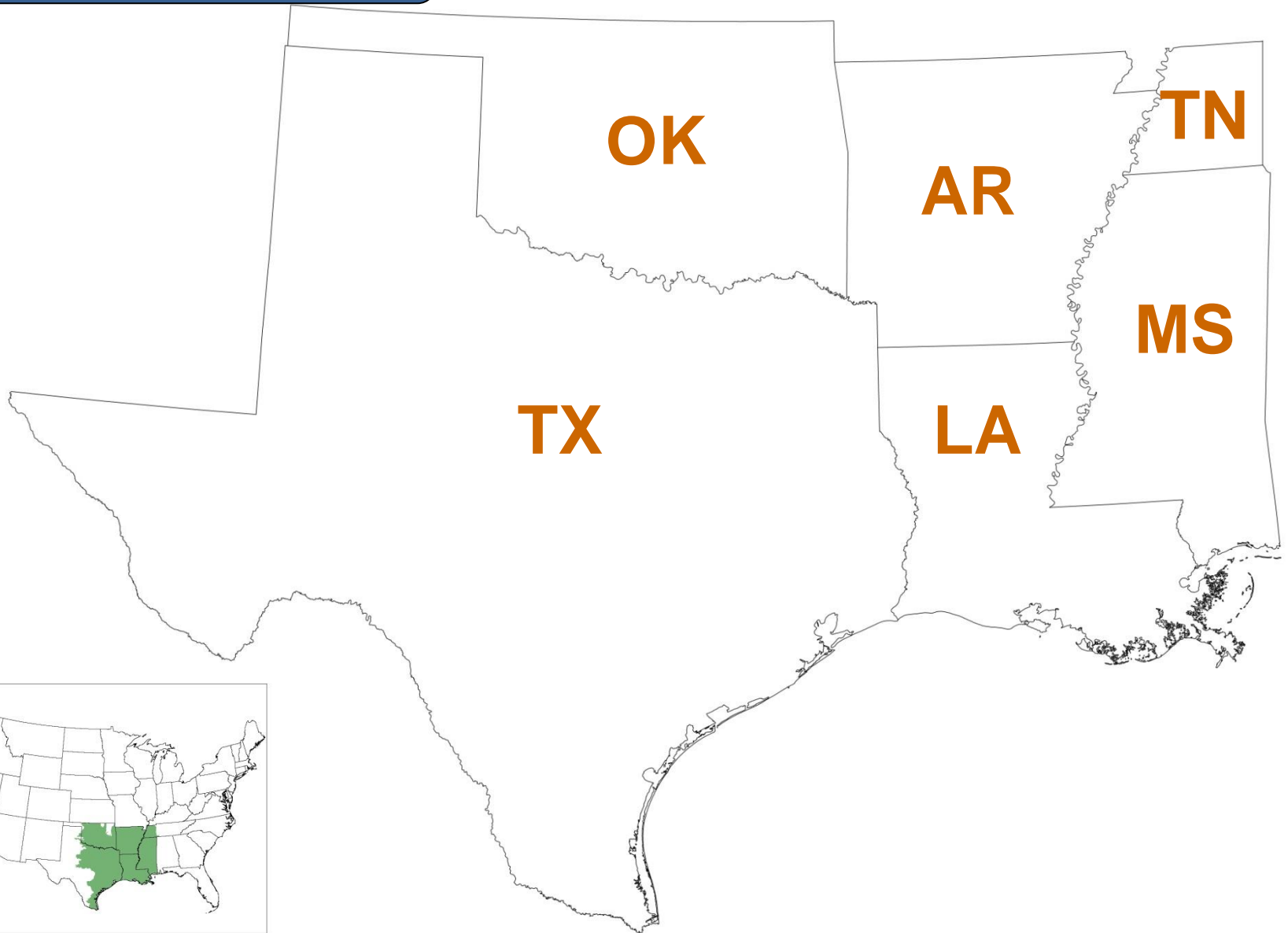
# Hg in Fish vs Hg Deposition



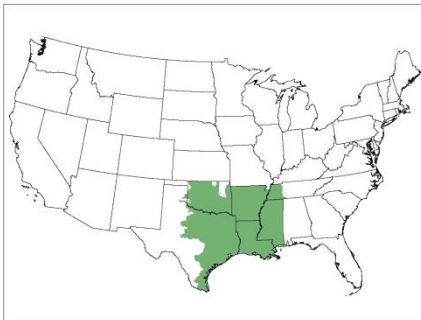


**What is level of Hg  
contamination in the  
south central US?**

# Study Area



# Study Area



**Largemouth Bass**





# Study Area



TN



TX



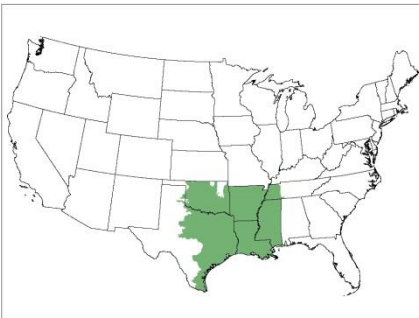
LA



MS



Largemouth Bass

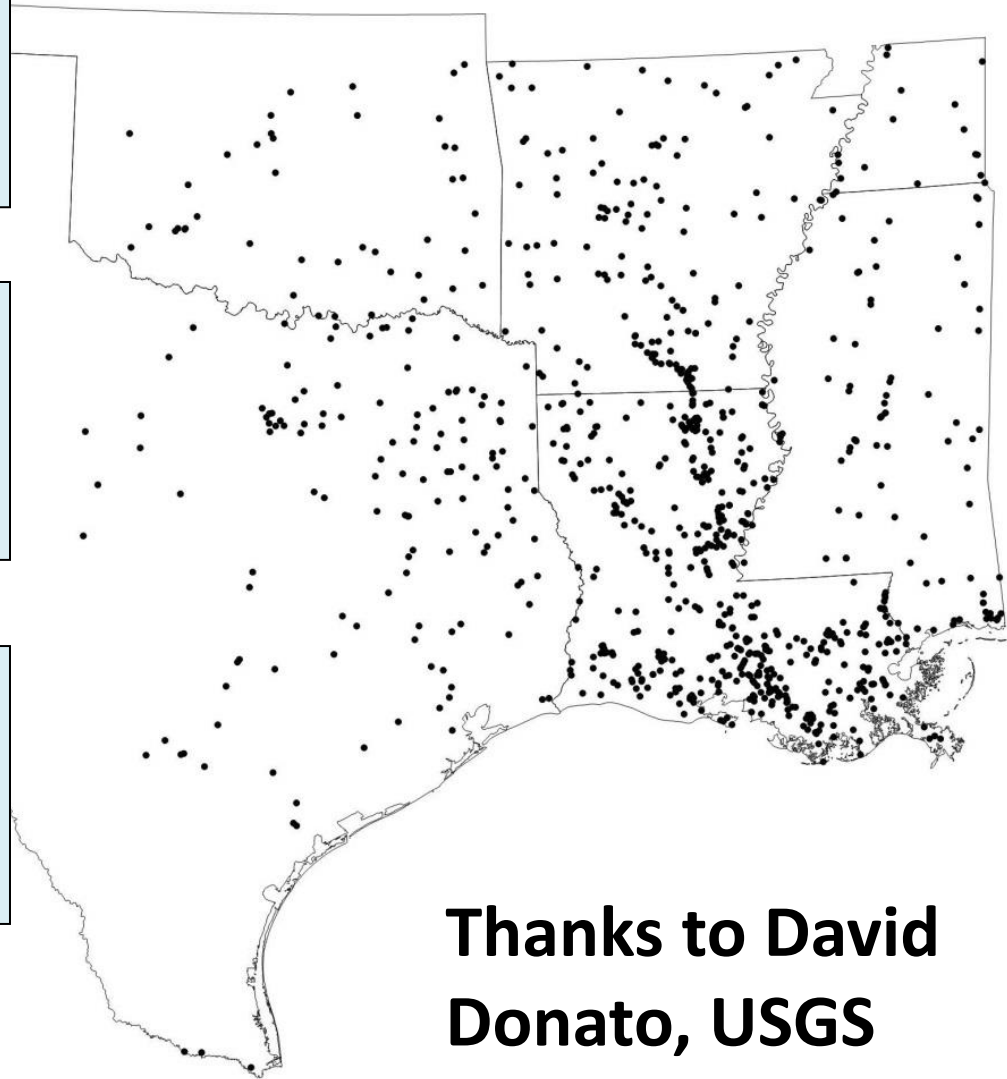


# Sites for Hg in LMB

**Data used with National Descriptive Model of Mercury in Fish**

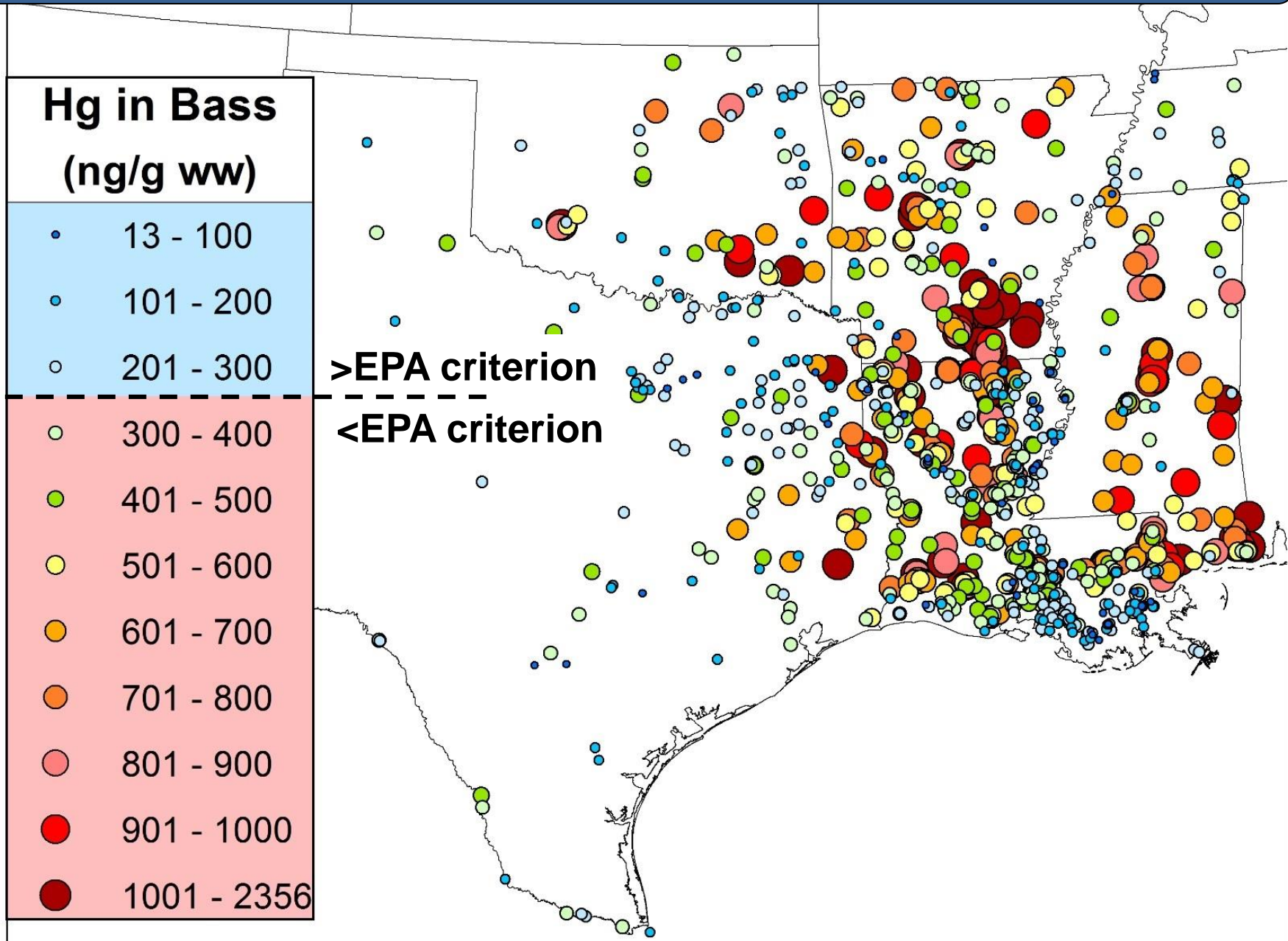
**Total data set of 40,564 fish samples collected from 1969 to 2010 at 893 lentic and lotic sites**

**Estimated Hg concentrations in 35.6 cm-TL largemouth bass equivalents**



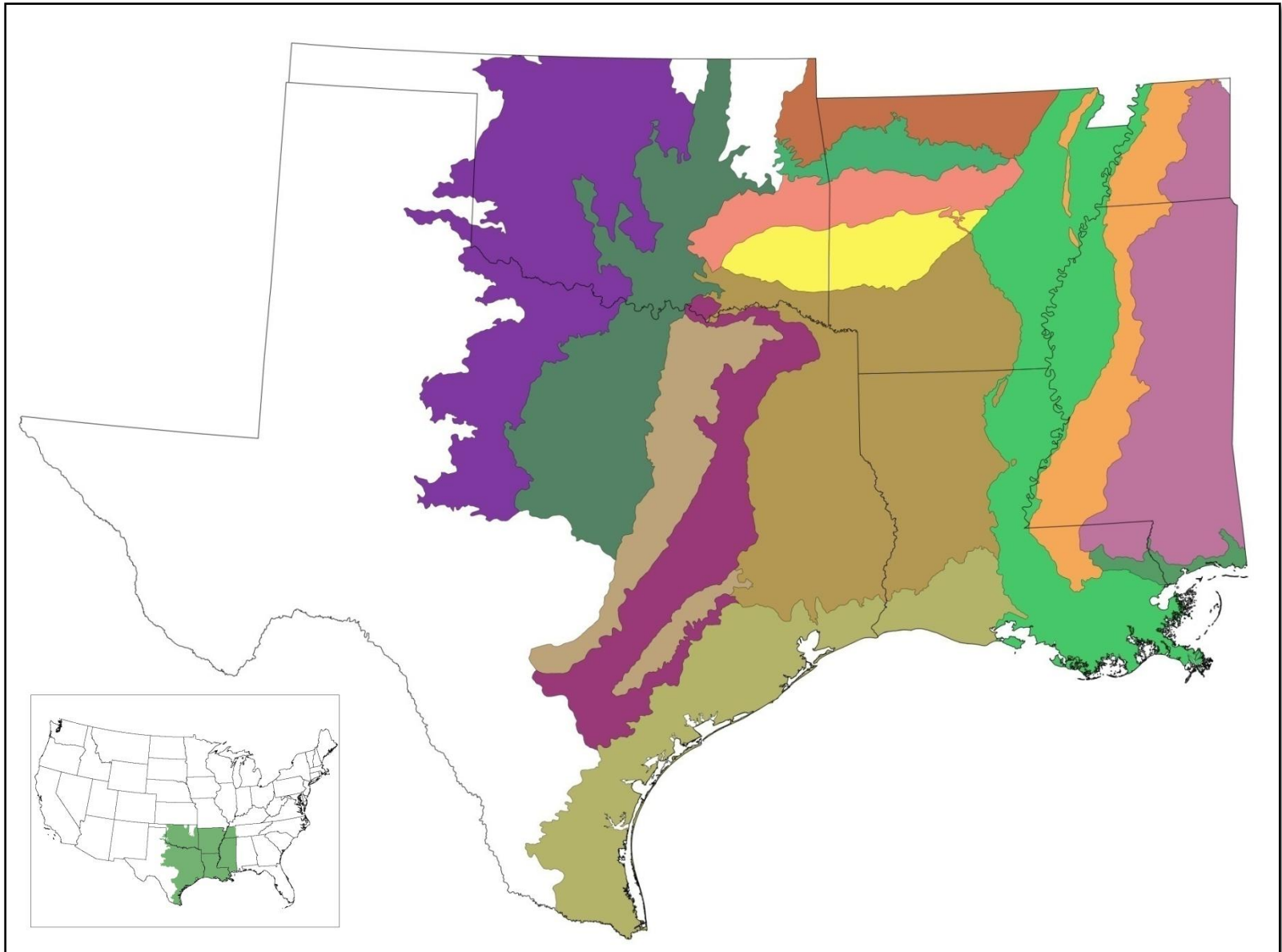
**Thanks to David Donato, USGS**

# Distribution of Mercury in the South Central US

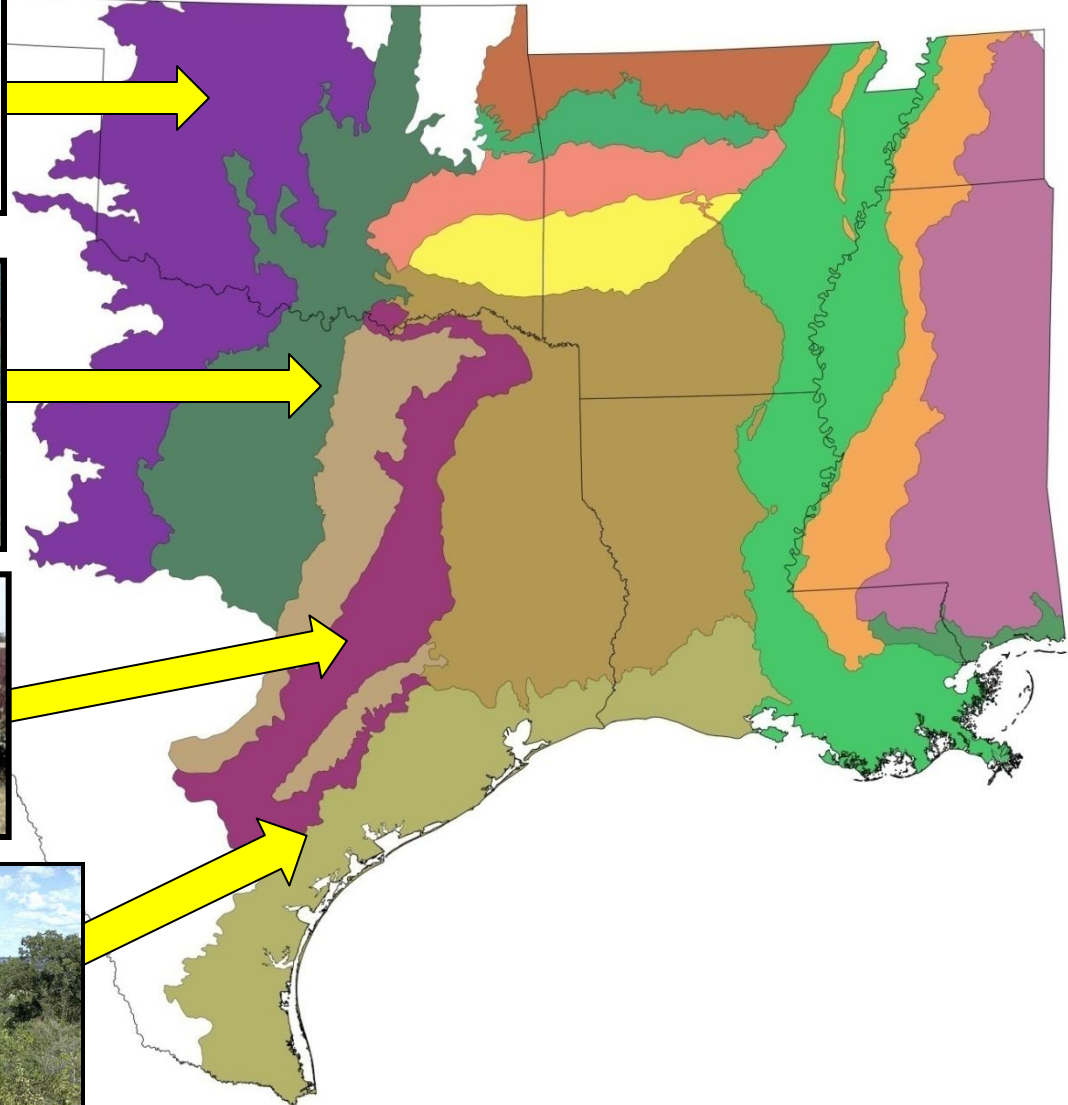




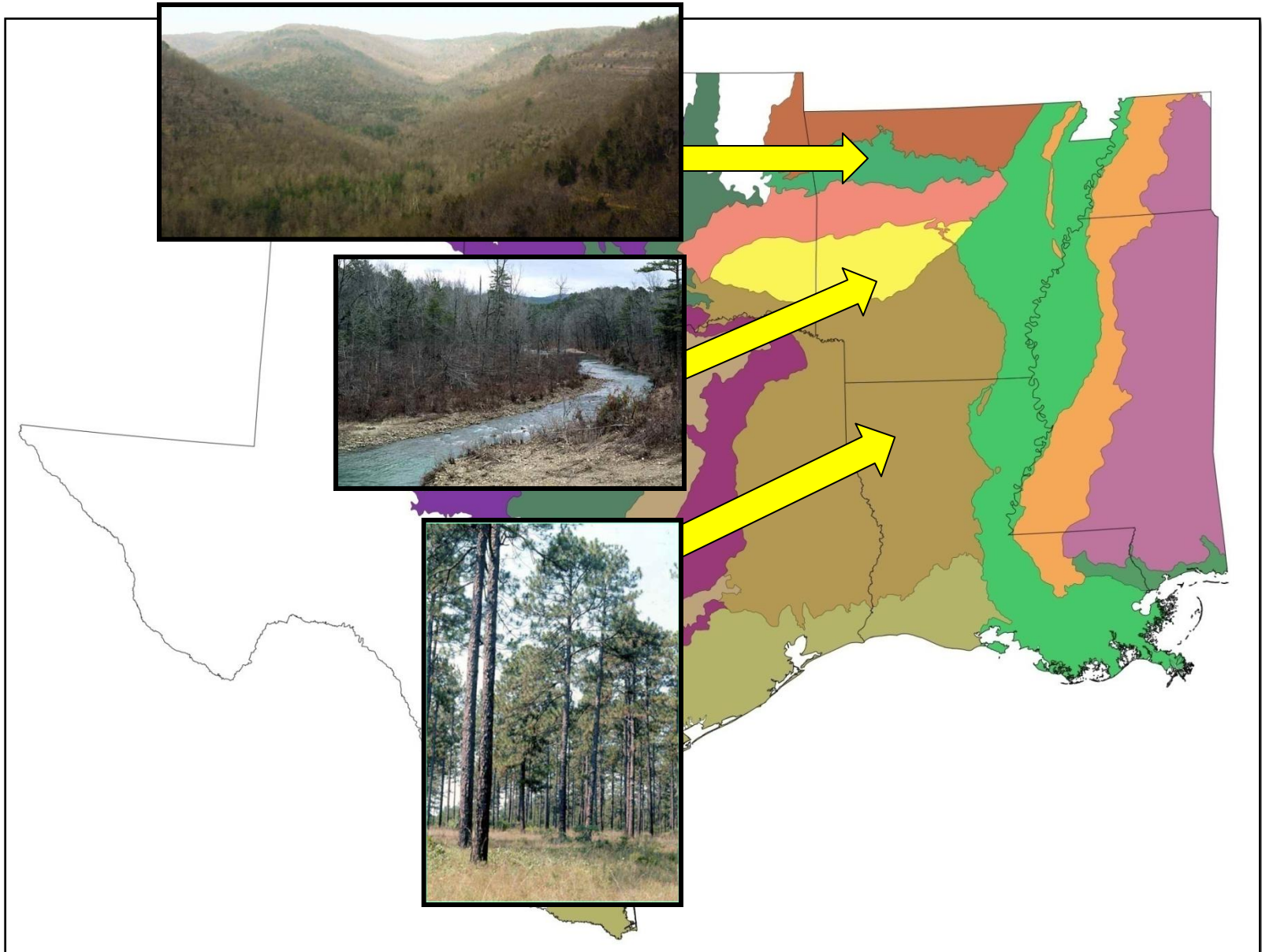
# U.S. EPA Level III Ecoregions



# U.S. EPA Level III Ecoregions

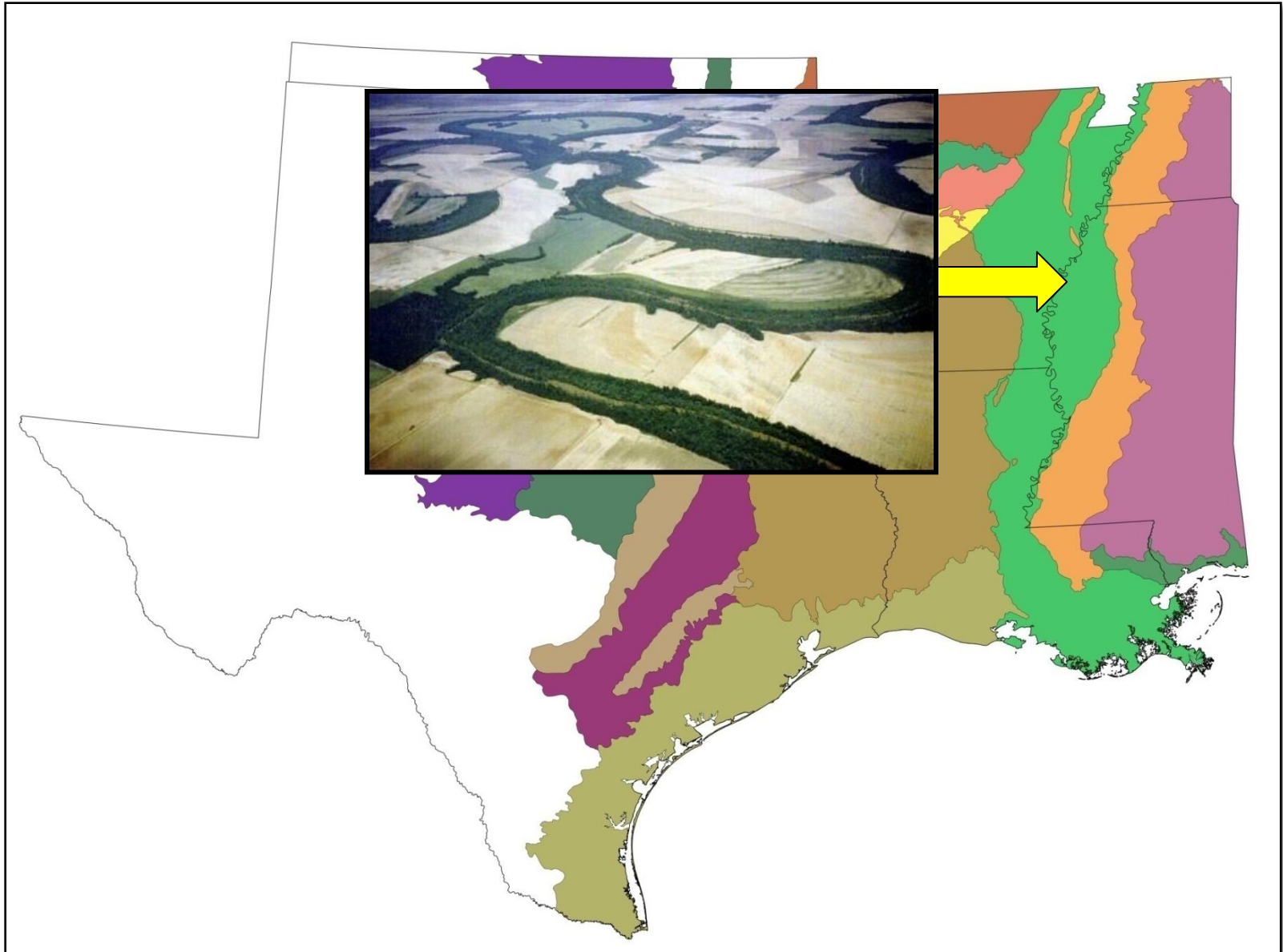


# U.S. EPA Level III Ecoregions

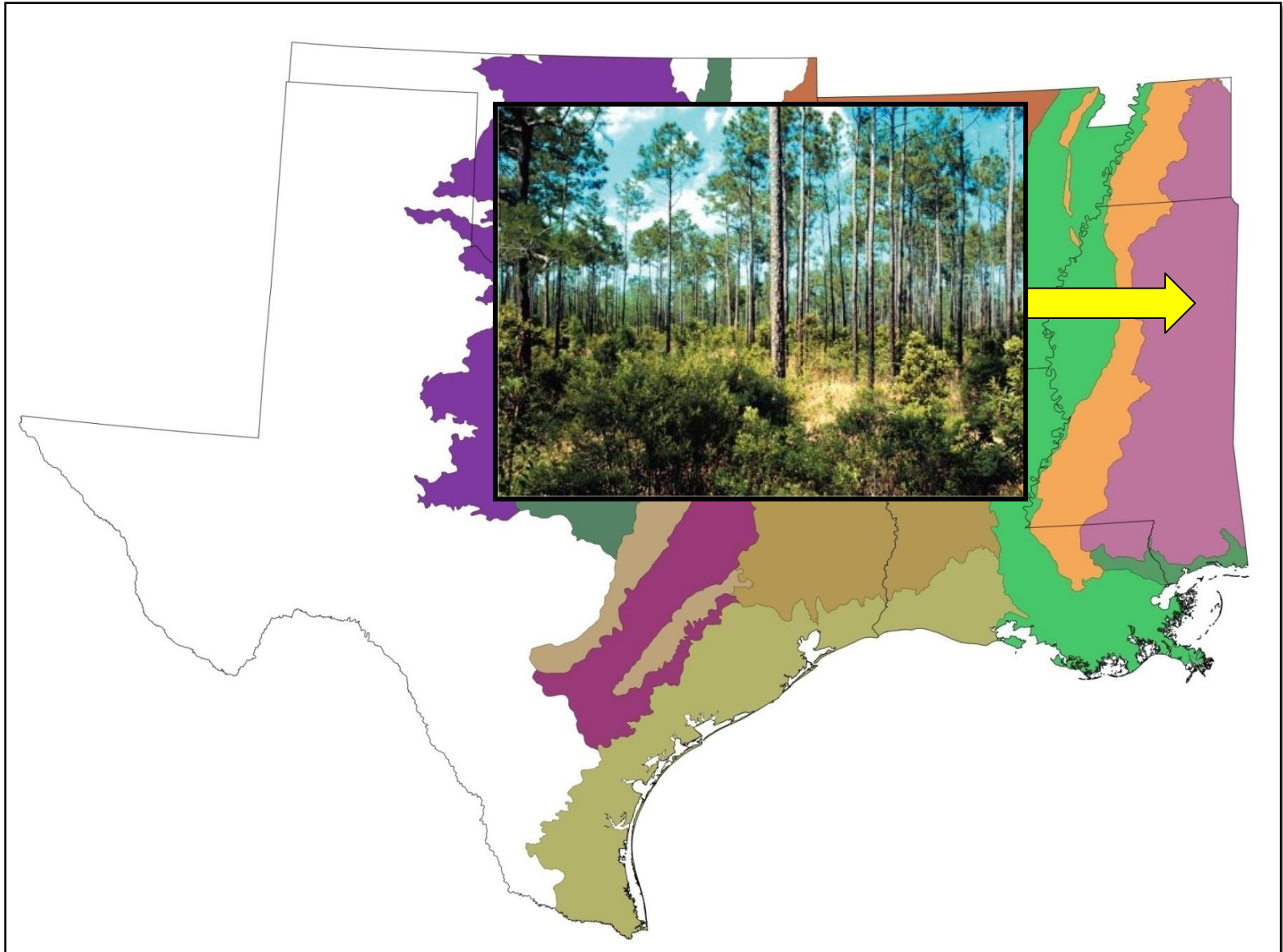




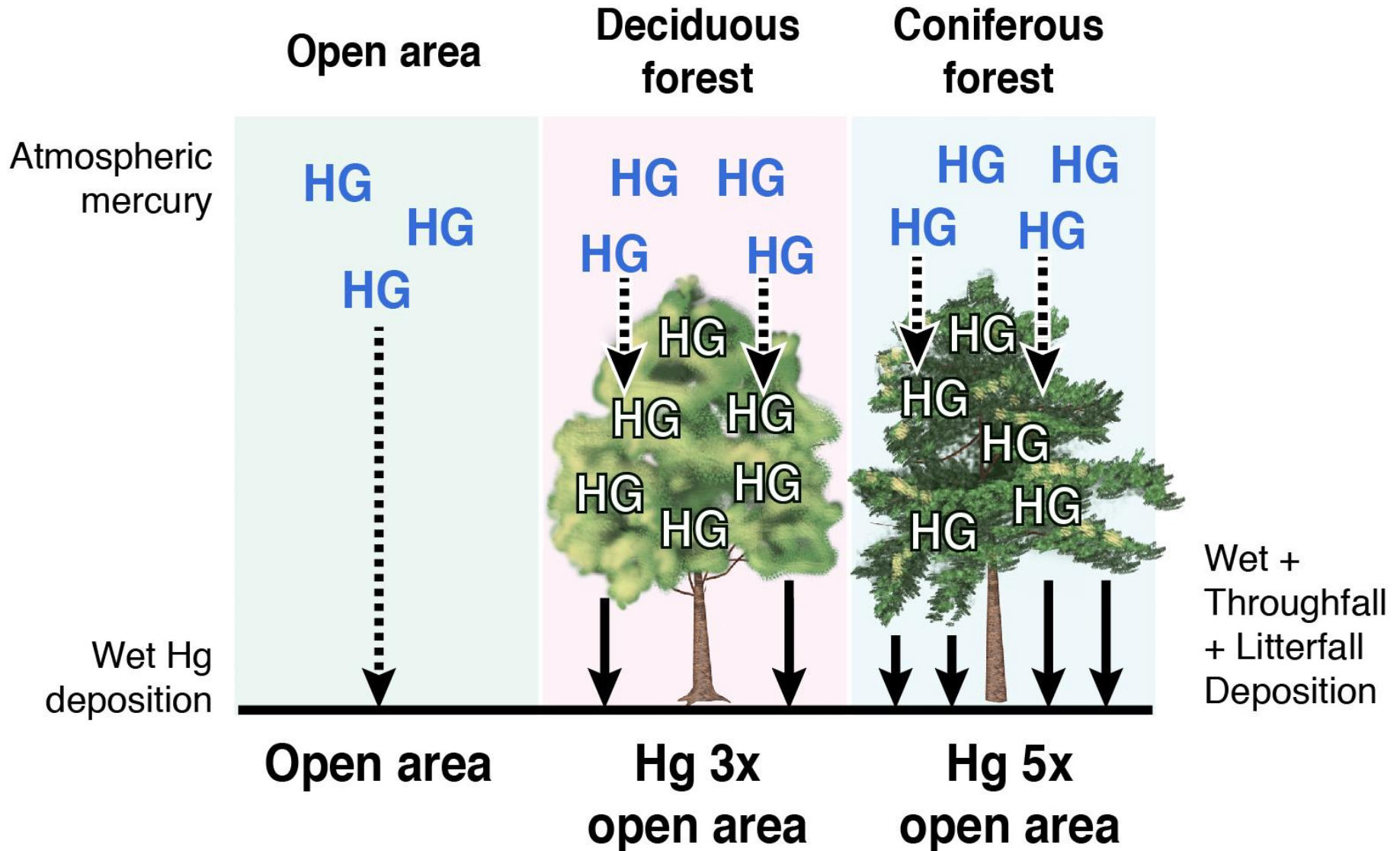
# U.S. EPA Level III Ecoregions



# U.S. EPA Level III Ecoregions



# Mercury Deposition in Open Areas, Deciduous Forests and Coniferous Forests



Based on Graydon et al. 2008



## **The Conifer Risk Hypothesis**

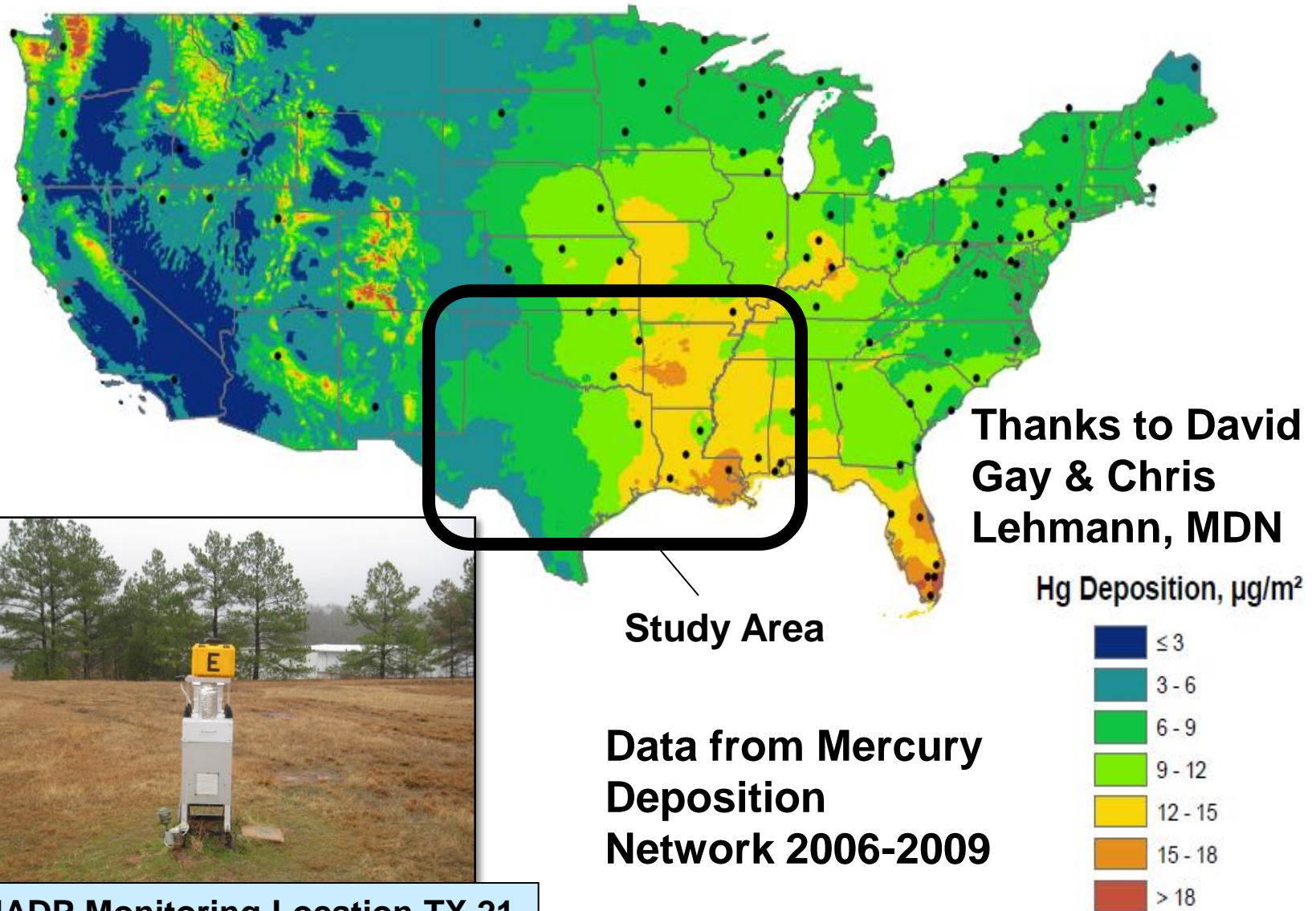
**“The greater efficiency of conifers at scavenging THg and MeHg from the atmosphere may increase the risk of mercury related water quality issues in conifer-dominated systems.”**

**Witt et al. 2009. Water, Air & Soil Pollution**

## **Objective of Study**

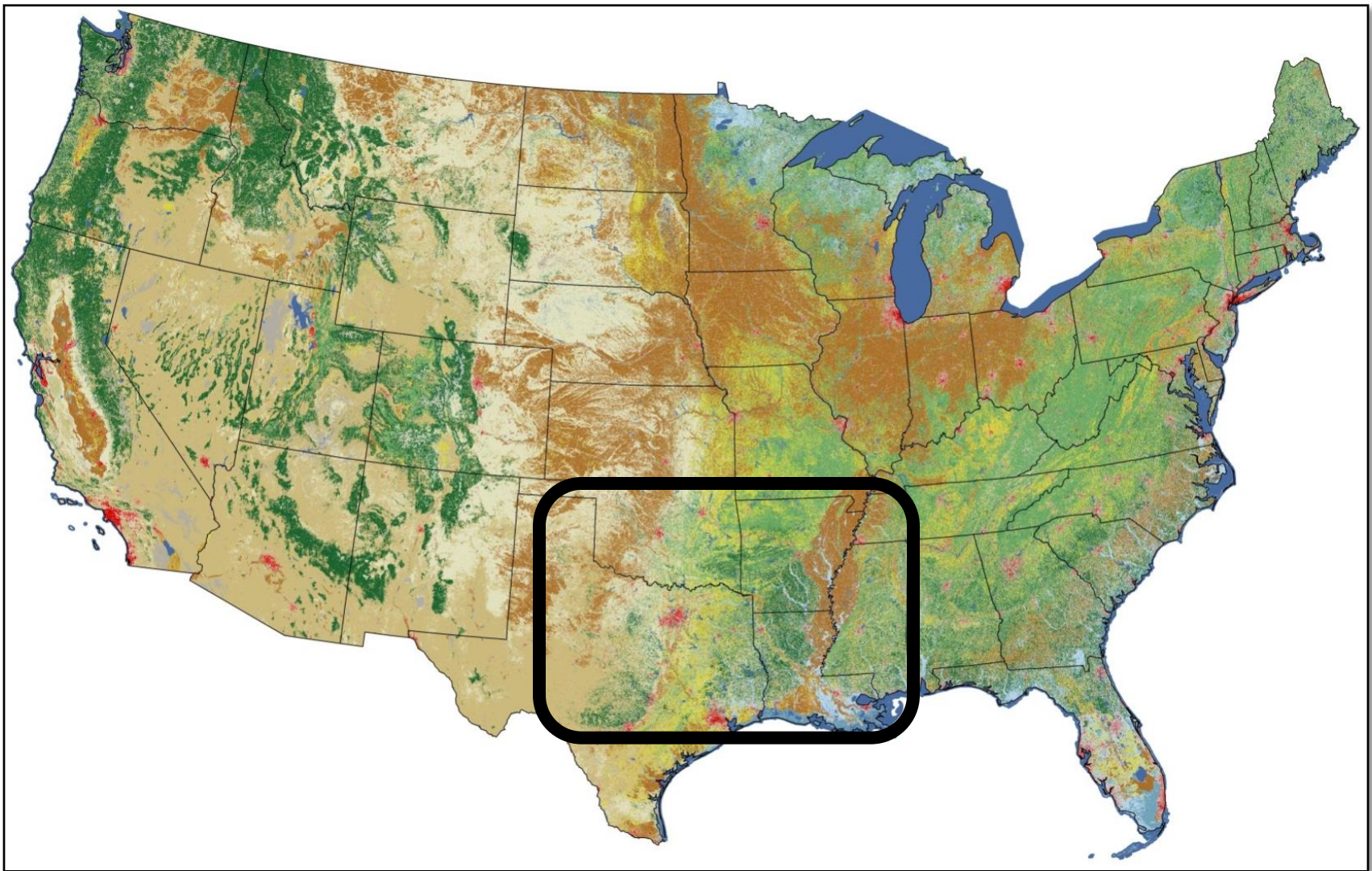
**Examine the relationship between Hg deposition, forest coverage and fish size on Hg contamination of fish in 14 ecoregions in the South Central U.S.**

# Wet Mercury Deposition in Open Areas



MDN/NADP Monitoring Location TX 21

# National Land Cover Database 2006

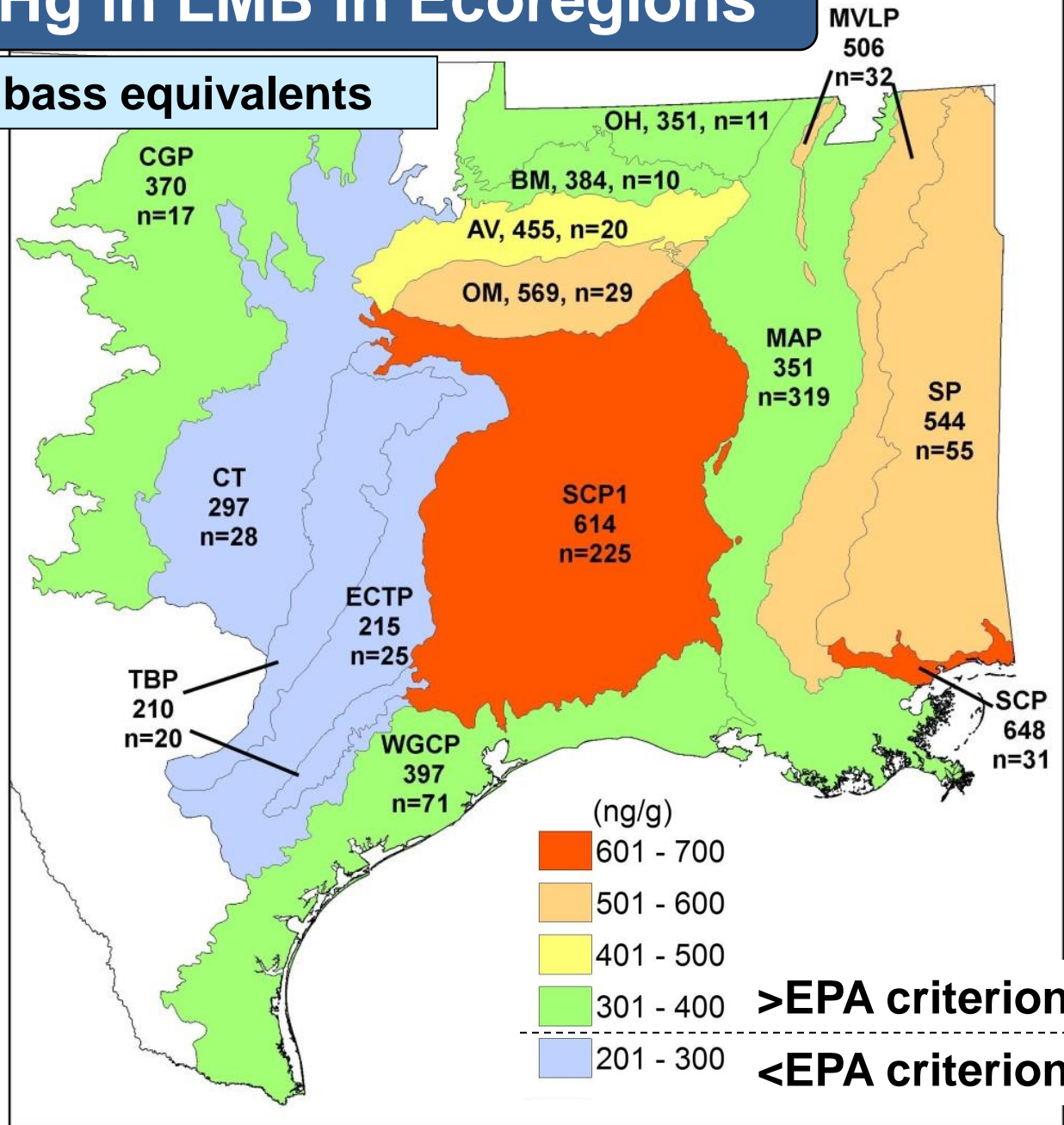


**National Land Cover Database 2006**  
**Multi-Resolution Land Characteristics Consortium**

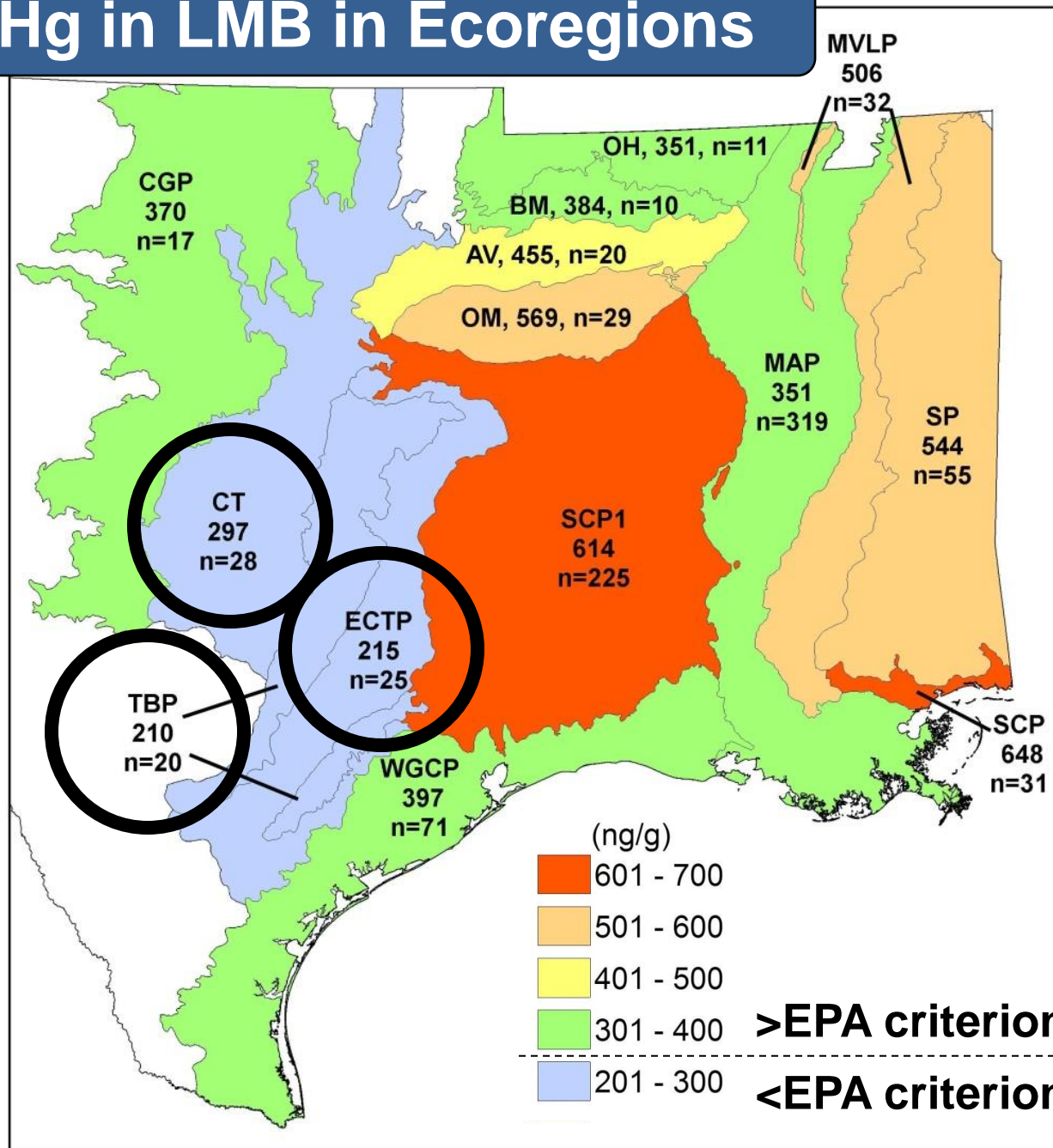


# Average Hg in LMB in Ecoregions

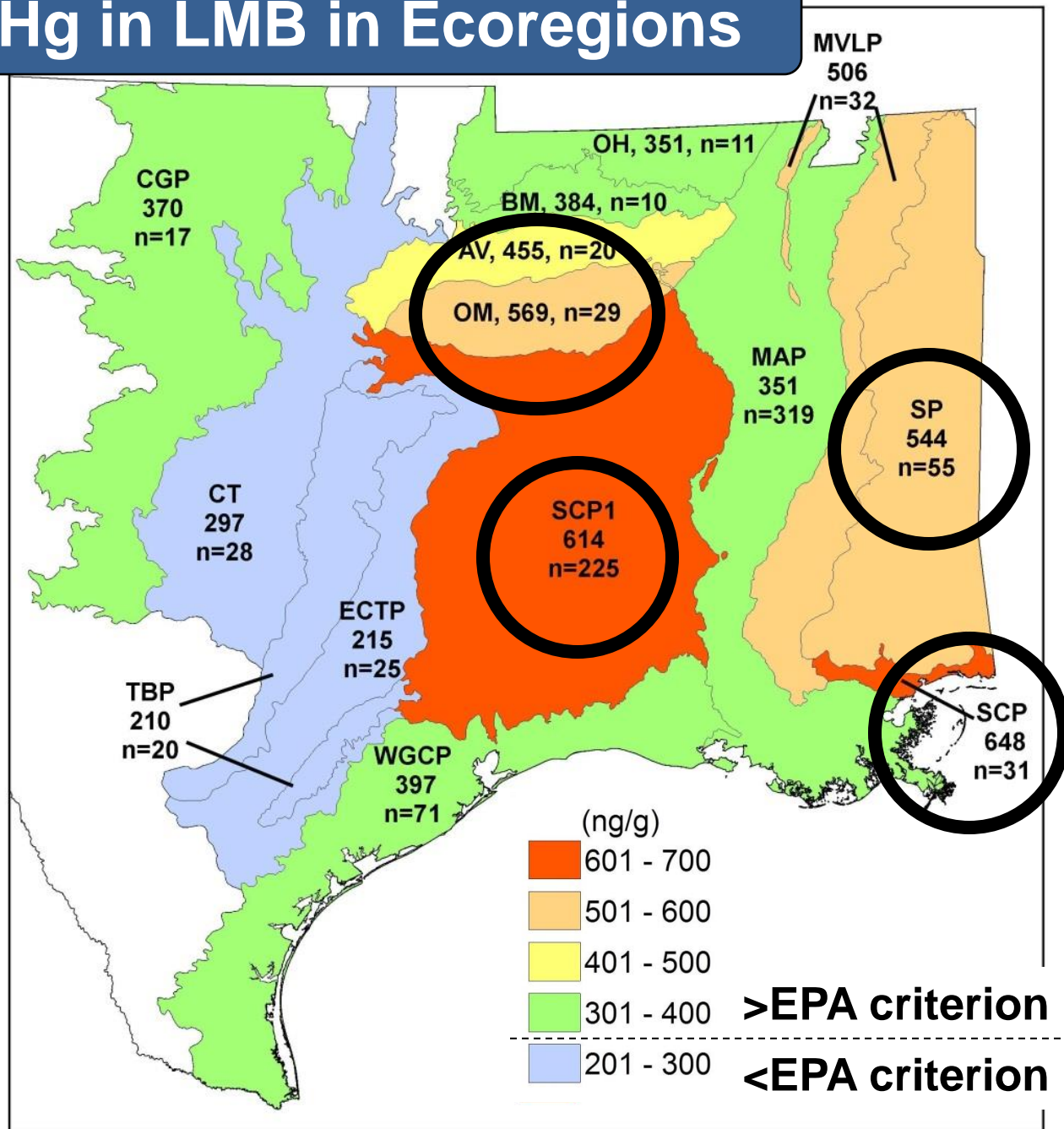
35.6 cm-TL bass equivalents



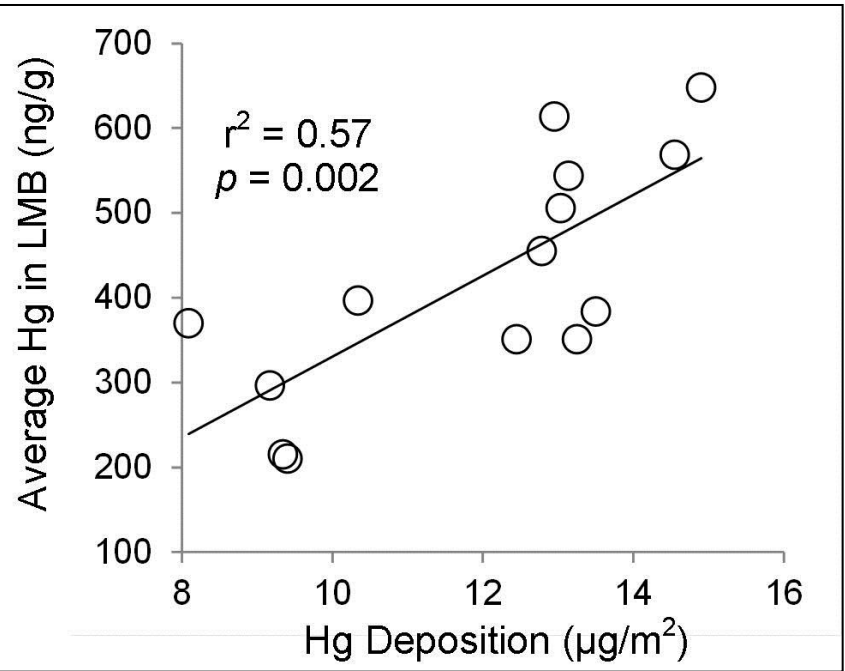
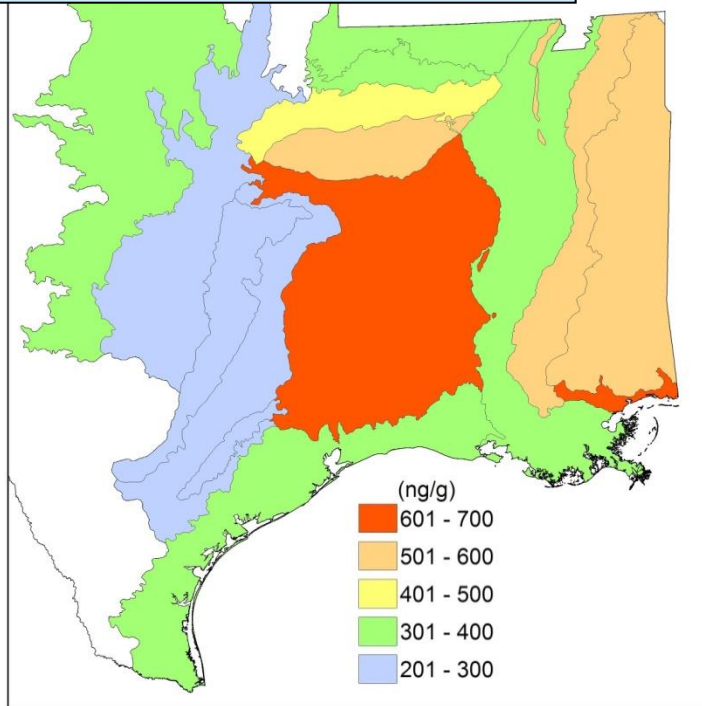
# Average Hg in LMB in Ecoregions



# Average Hg in LMB in Ecoregions

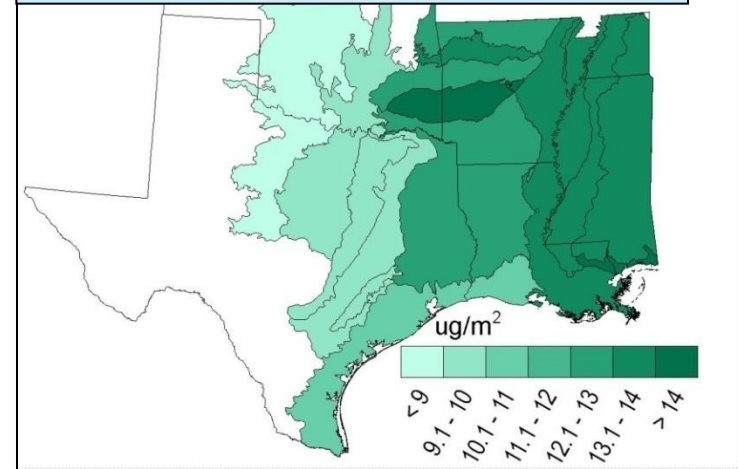


## Hg in Largemouth Bass



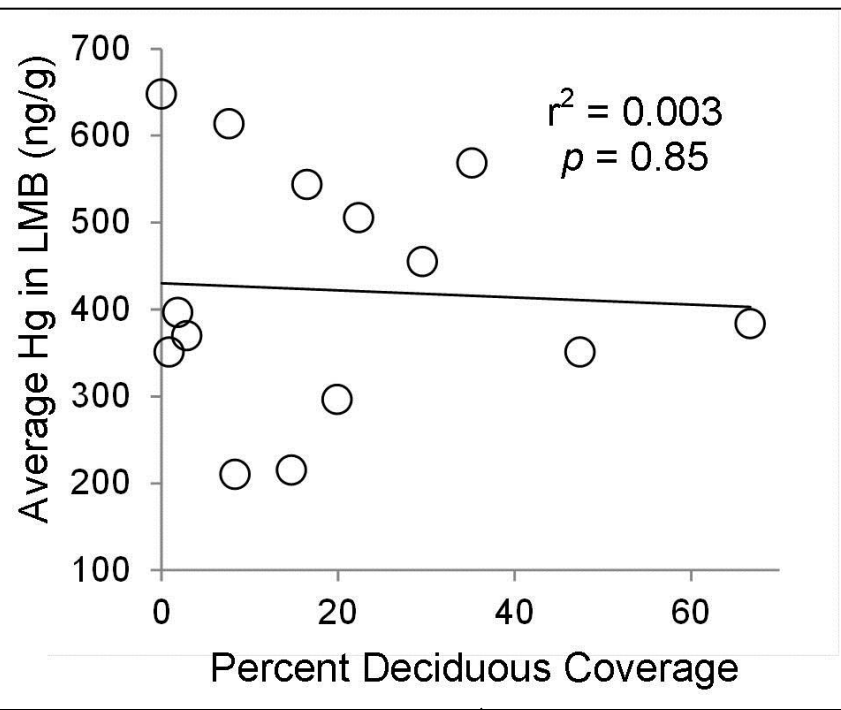
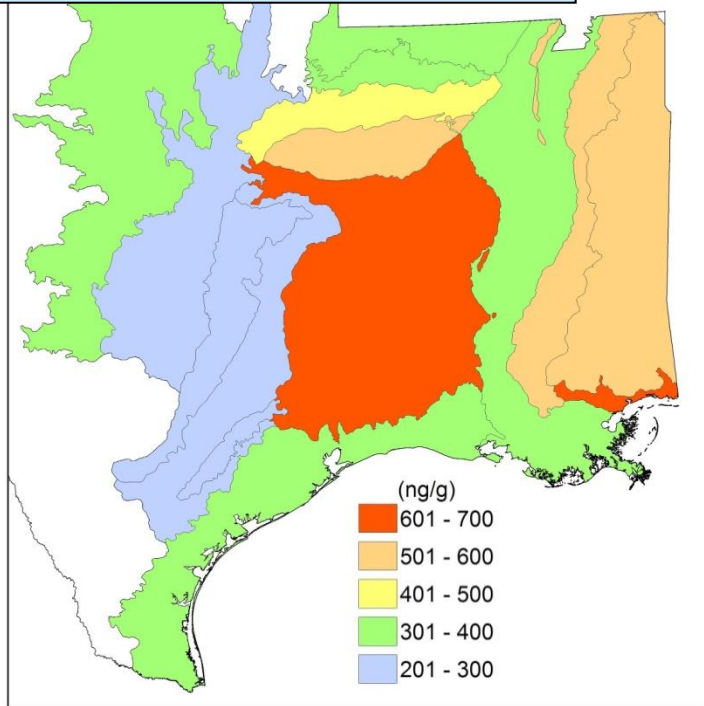
## Hg in LMB vs Wet Hg Deposition

## Average Wet Hg Deposition



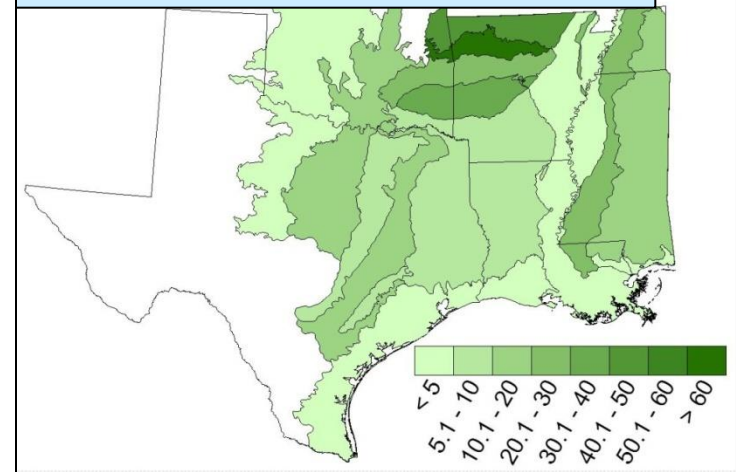


## Hg in Largemouth Bass

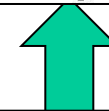
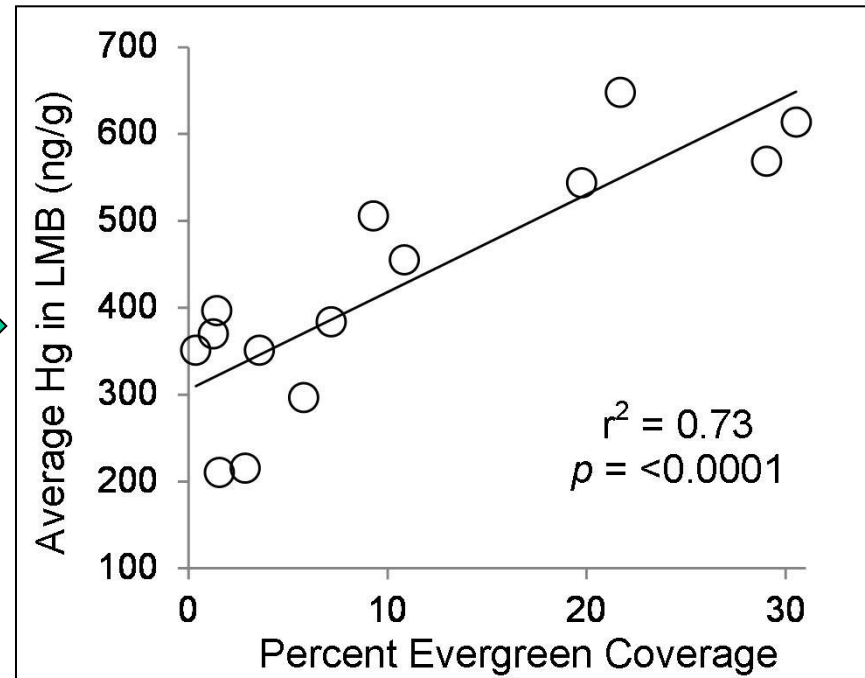
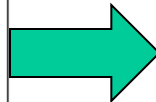
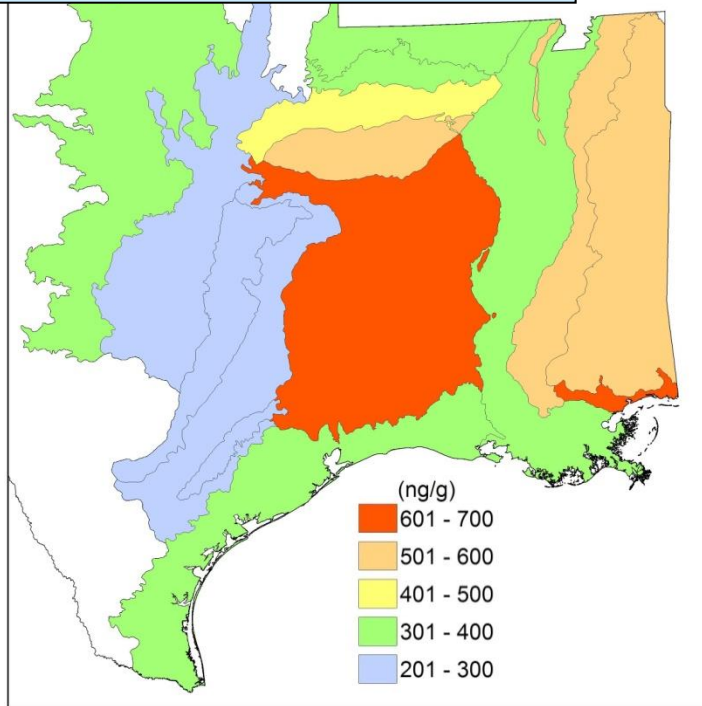


## Hg in LMB vs Deciduous Forests

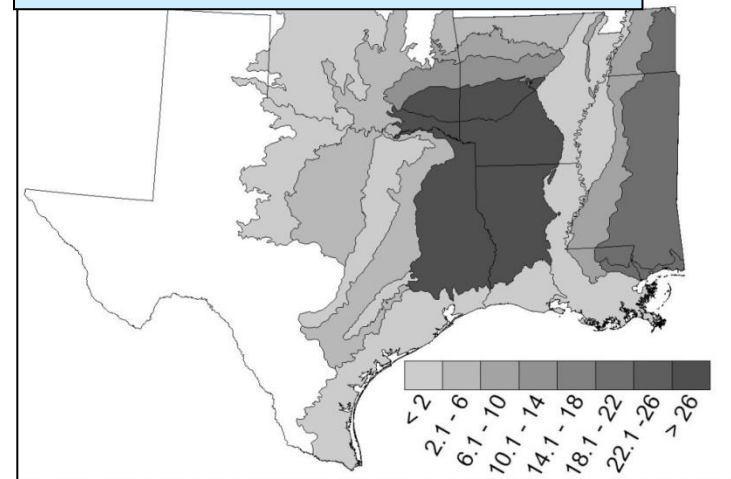
## Percent Deciduous Forest



## Hg in Largemouth Bass



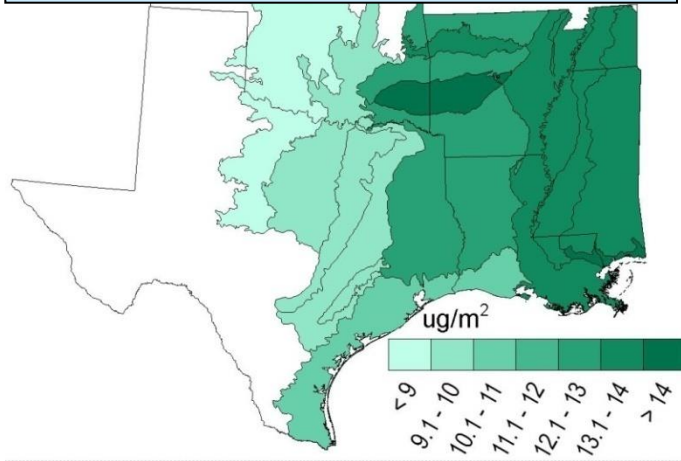
## Percent Evergreen Forest



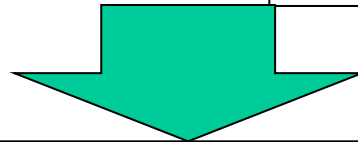
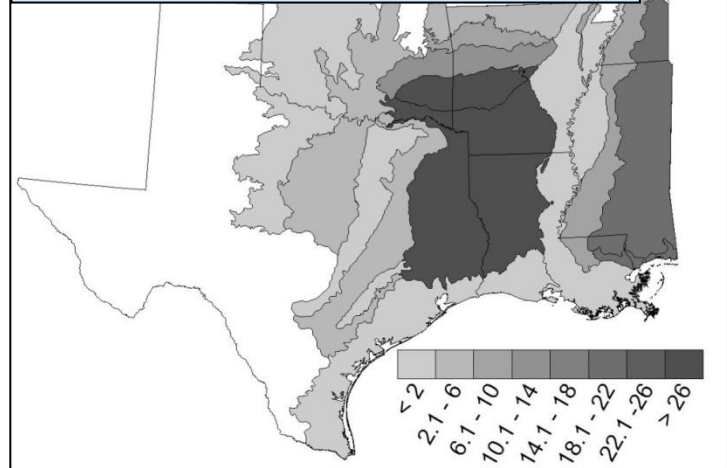
**Hg in LMB  
vs  
Evergreen Forests**

# Adjusting for Conifer Effects on Hg Dep

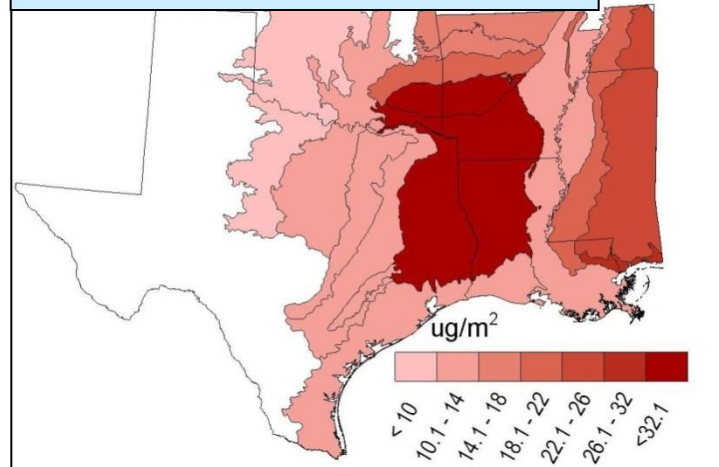
Average Wet Hg Deposition



Percent Evergreen Forest

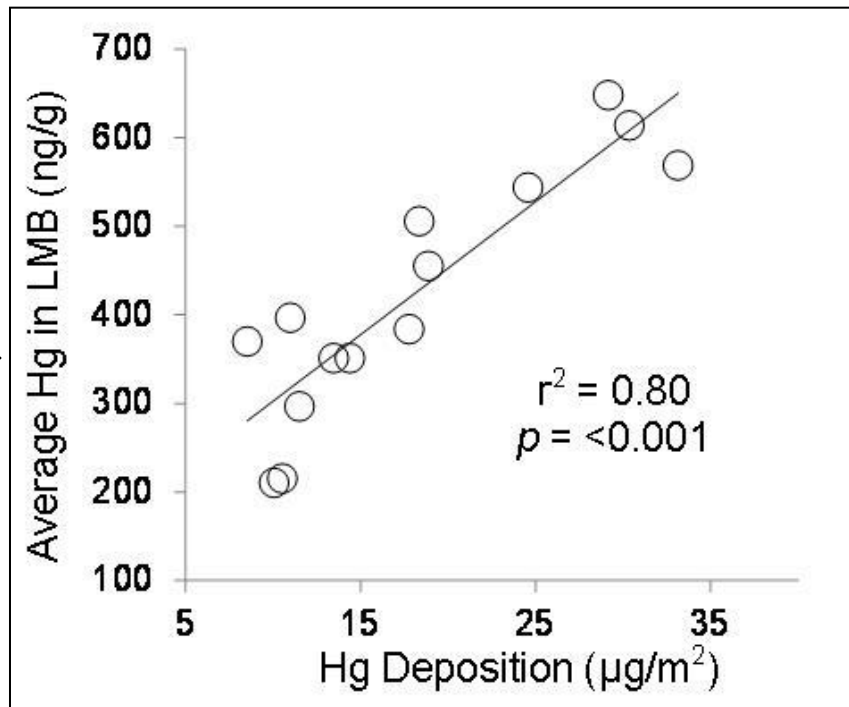
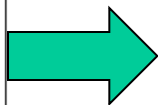
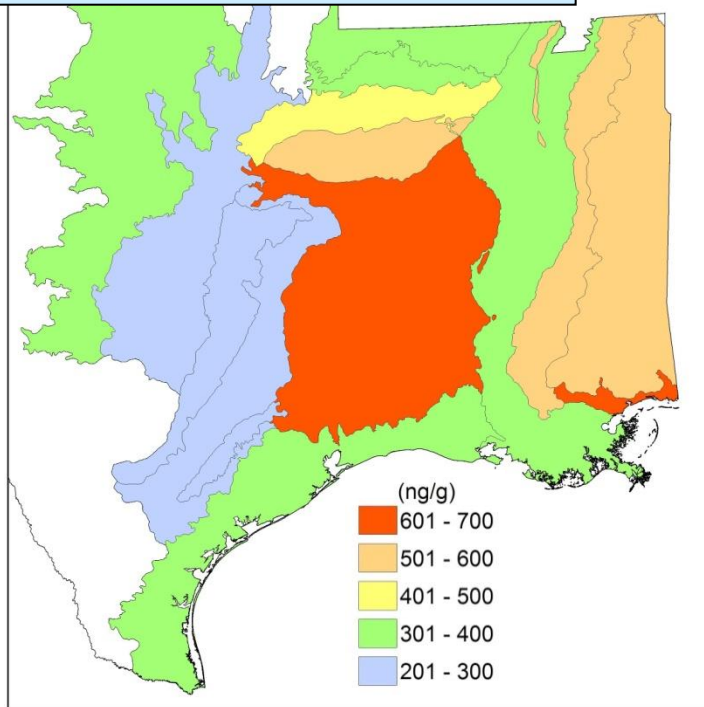


Adjusted Hg Deposition

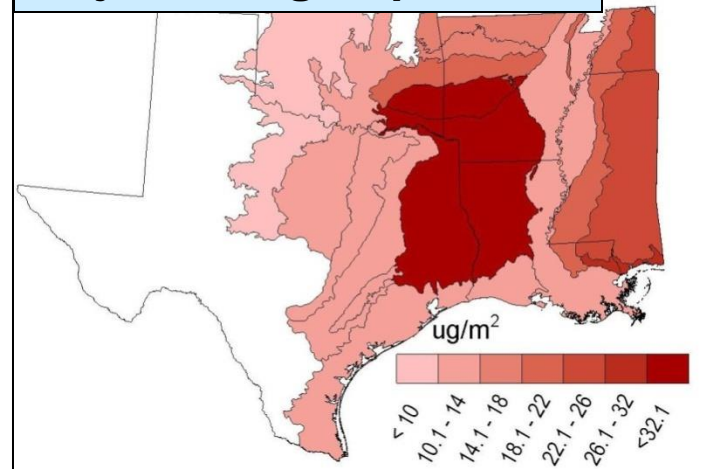


**Wet  
+  
Throughfall  
+  
Litterfall**

## Hg in Largemouth Bass



## Adjusted Hg Deposition



# Hg in LMB

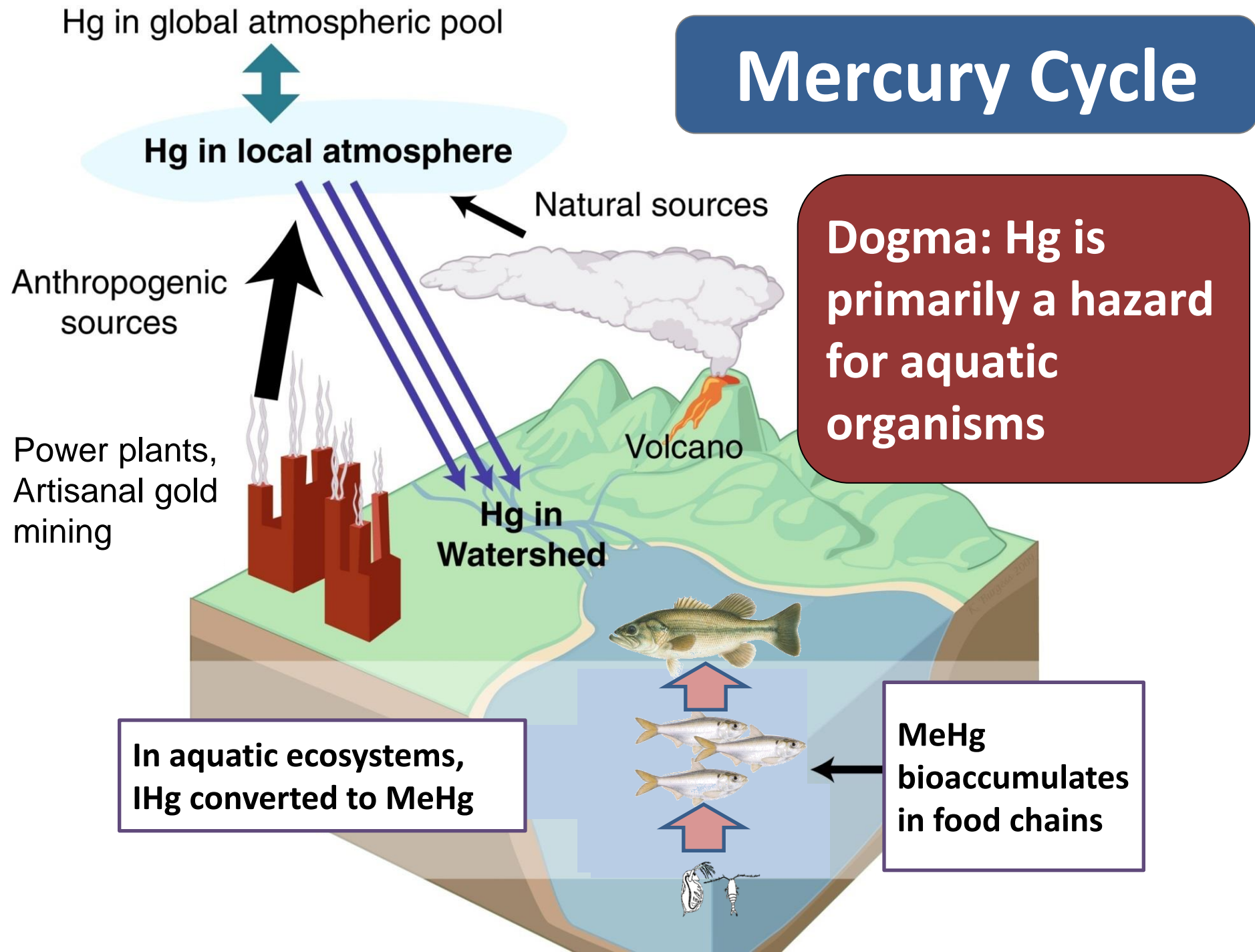
# vs

# Adjusted Hg Deposition

From Drenner et al. 2013.  
ES&T



# Mercury Cycle



# Hg in Terrestrial Consumers

Science



## The Movement of Aquatic Mercury Through Terrestrial Food Webs

Daniel A. Cristol,\* Rebecka L. Brasso, Anne M. Condon, Rachel E. Fovargue, Scott L. Friedman, Kelly K. Hallinger, Adrian P. Monroe, Ariel E. White

*The Condor* 112(4):789–799  
© The Cooper Ornithological Society 2010

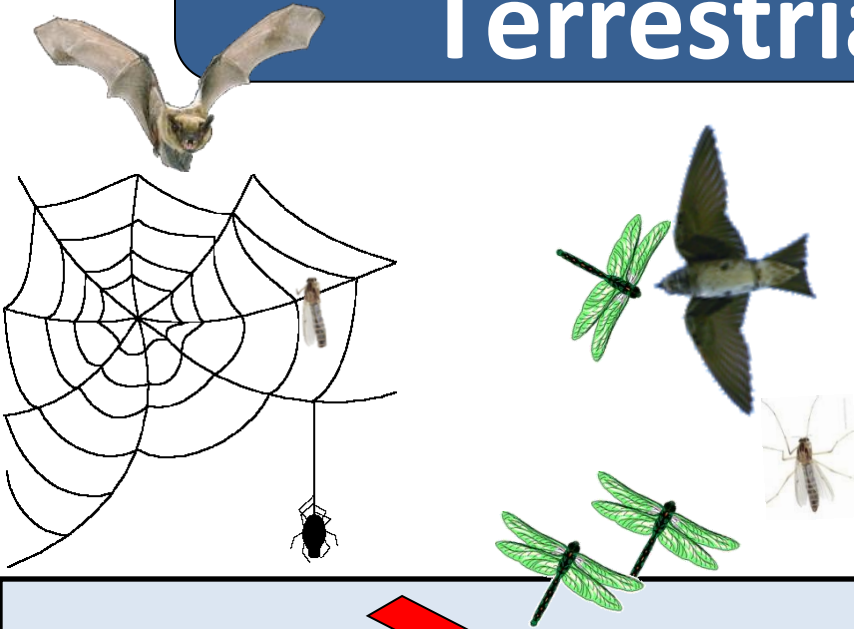
## GEOGRAPHIC AND SEASONAL VARIATION IN MERCURY EXPOSURE OF THE DECLINING RUSTY BLACKBIRD

*Ecotoxicology* (2014) 23:45–55  
DOI 10.1007/s10646-013-1150-1

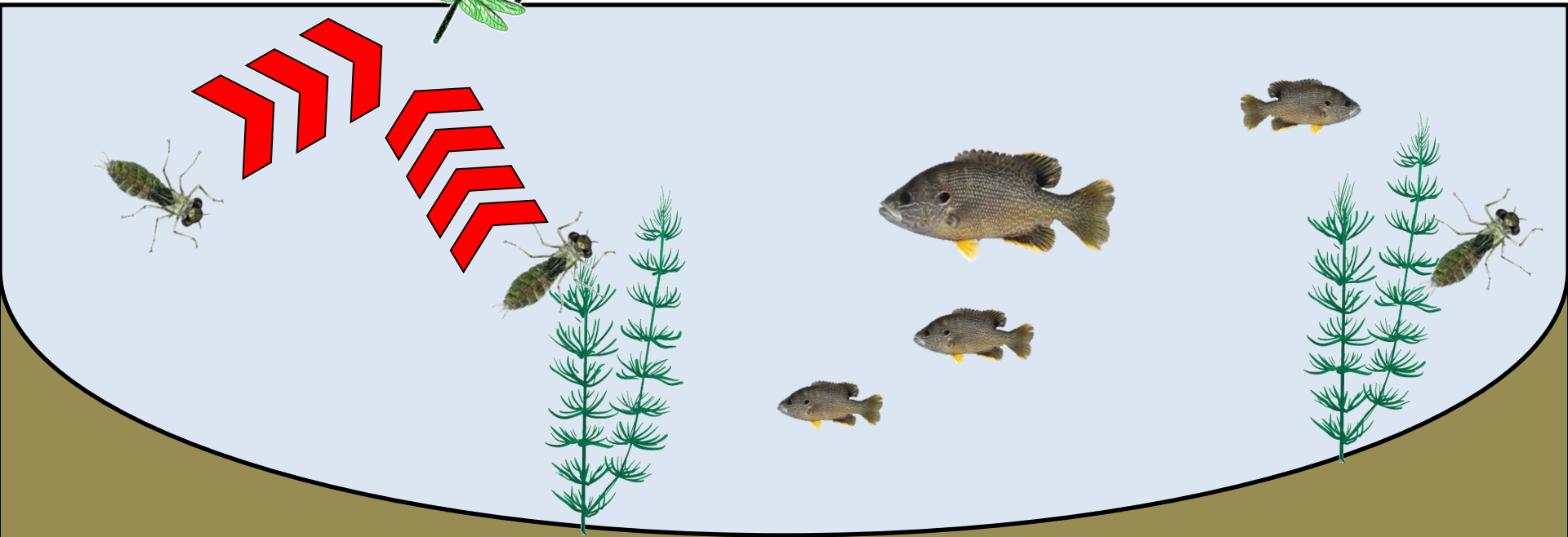
## Mercury in bats from the northeastern United States



# Transport of Contaminants to Terrestrial Consumers



**Cristol et al. 2008 Science;  
Gerrard and St. Louis 2001 ES&T;  
Raikow et al. 2011 Ecol. Appl. ;  
Sullivan and Rodewald 2012 ET&C;  
Tweedy et al. ES&T;  
Walters et al. 2008 Ecol. Appl.;  
and others...**



**What factors regulate the movement of Hg from aquatic to terrestrial ecosystems via emergent insects?**



**Top-Down Effect  
of Fish Predation**



**Movement of Hg from  
aquatic to terrestrial  
ecosystems**



**Bottom-Up Effect  
of Nutrients**

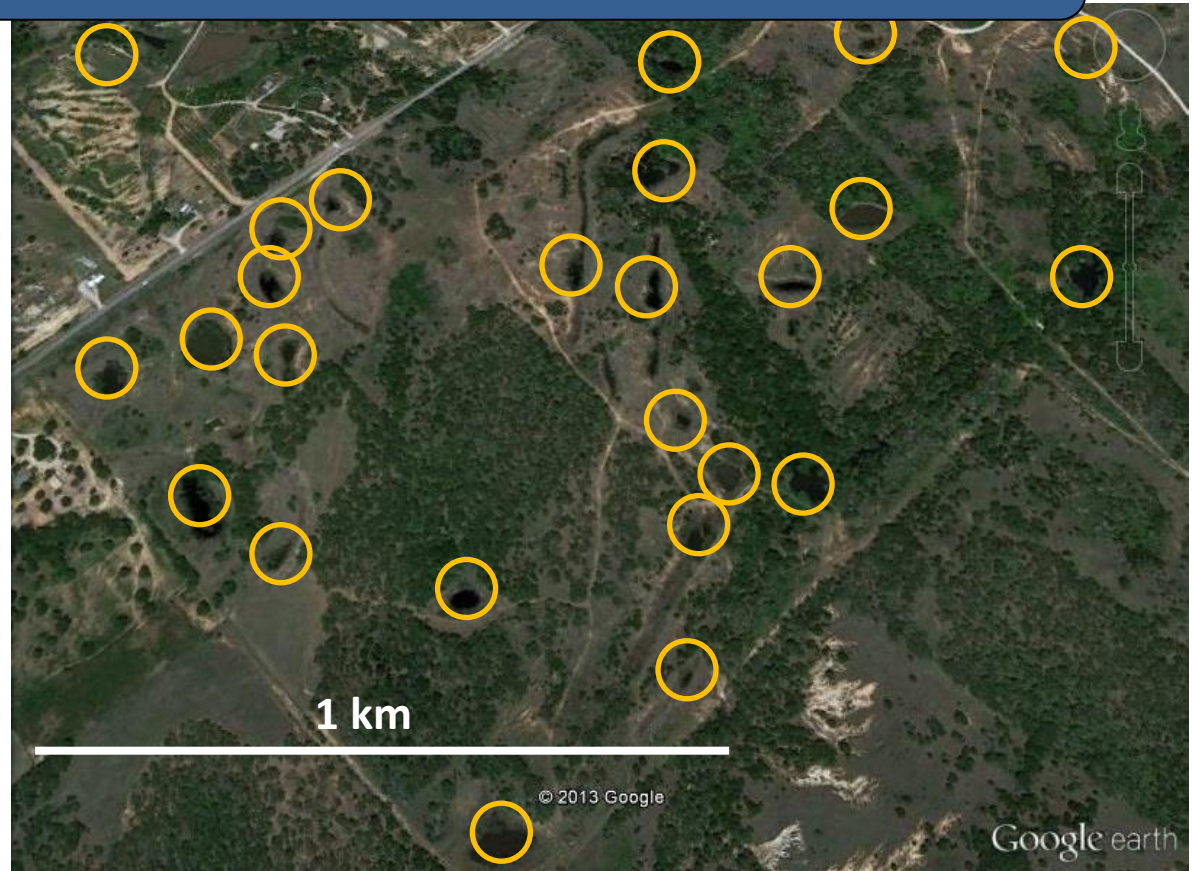
**Research  
Objective**

**Determine the  
effects of  
nutrients and the  
presence of fish  
on Hg flux from  
aquatic systems.**

# Research Questions

- 1. Do fish affect Hg contamination of macroinvertebrate communities?**
2. Do fish affect insect-mediated MeHg flux from experimental ponds?

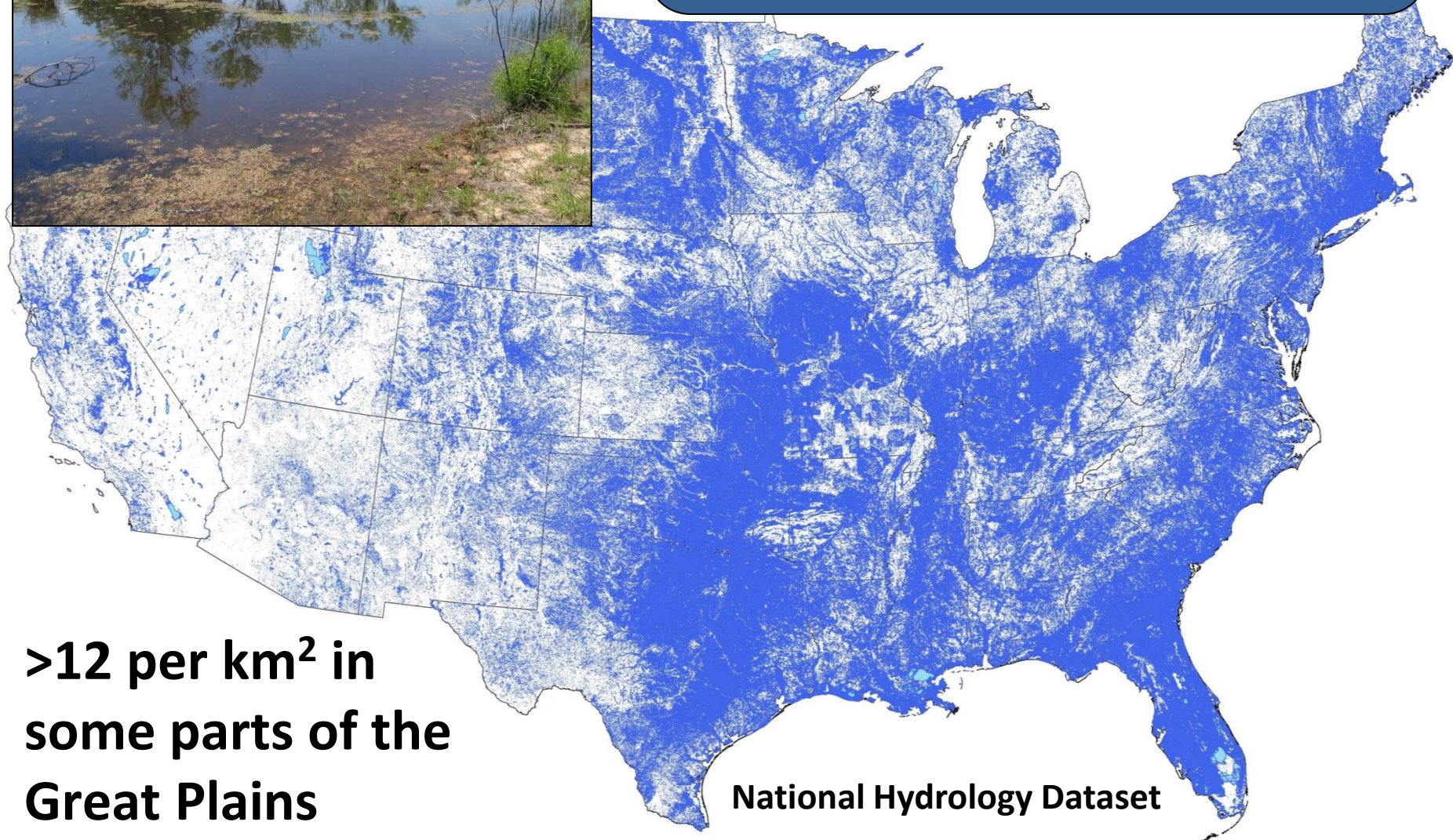
# Study Site: LBJ National Grassland



- Federally managed grassland in northern Texas
- ~900 man-made ponds in 120 km<sup>2</sup>
- Contaminated with Hg from the atmosphere
- Insect communities contain high concentrations of Hg (Blackwell and Drenner 2009 Southwest. Nat.)



# Distribution of small ponds in US



**>12 per km<sup>2</sup> in  
some parts of the  
Great Plains**

**National Hydrology Dataset**



# Pond drying



**Temporary Ponds  
dry annually**



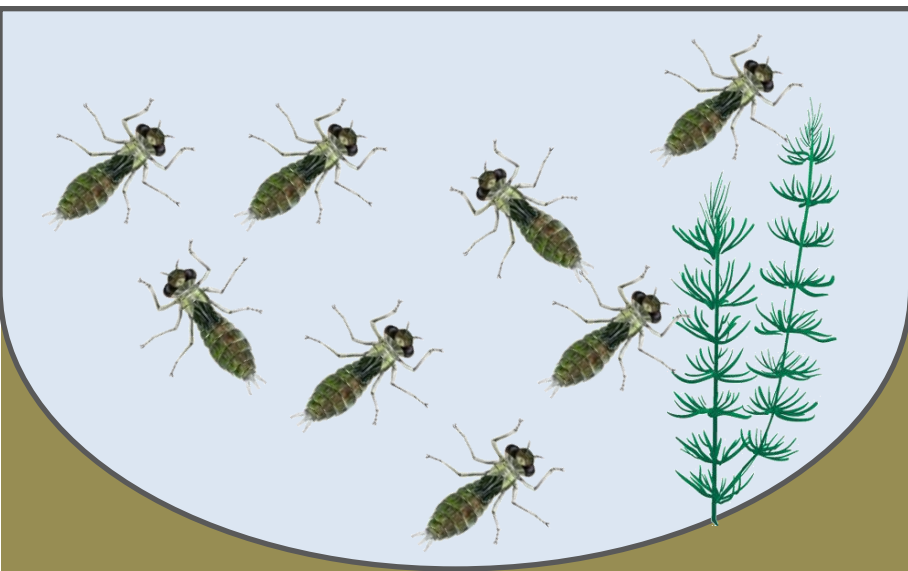
**Permanent ponds  
do not dry**

**Permanence Gradient**

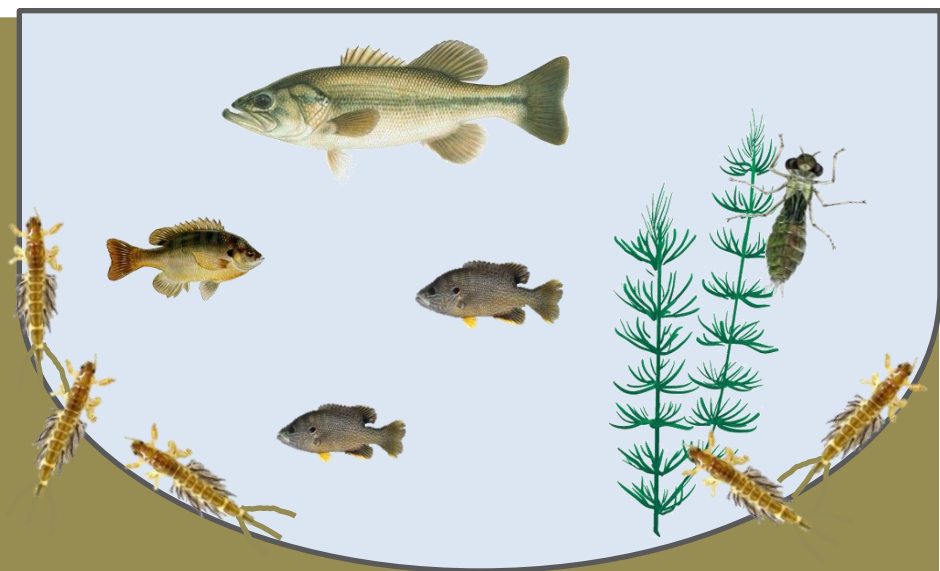
# Effect of permanence on community composition

Permanence Gradient

**Temporary Pond -  
Fishless**



**Permanent Pond – with  
fish**



# Study design

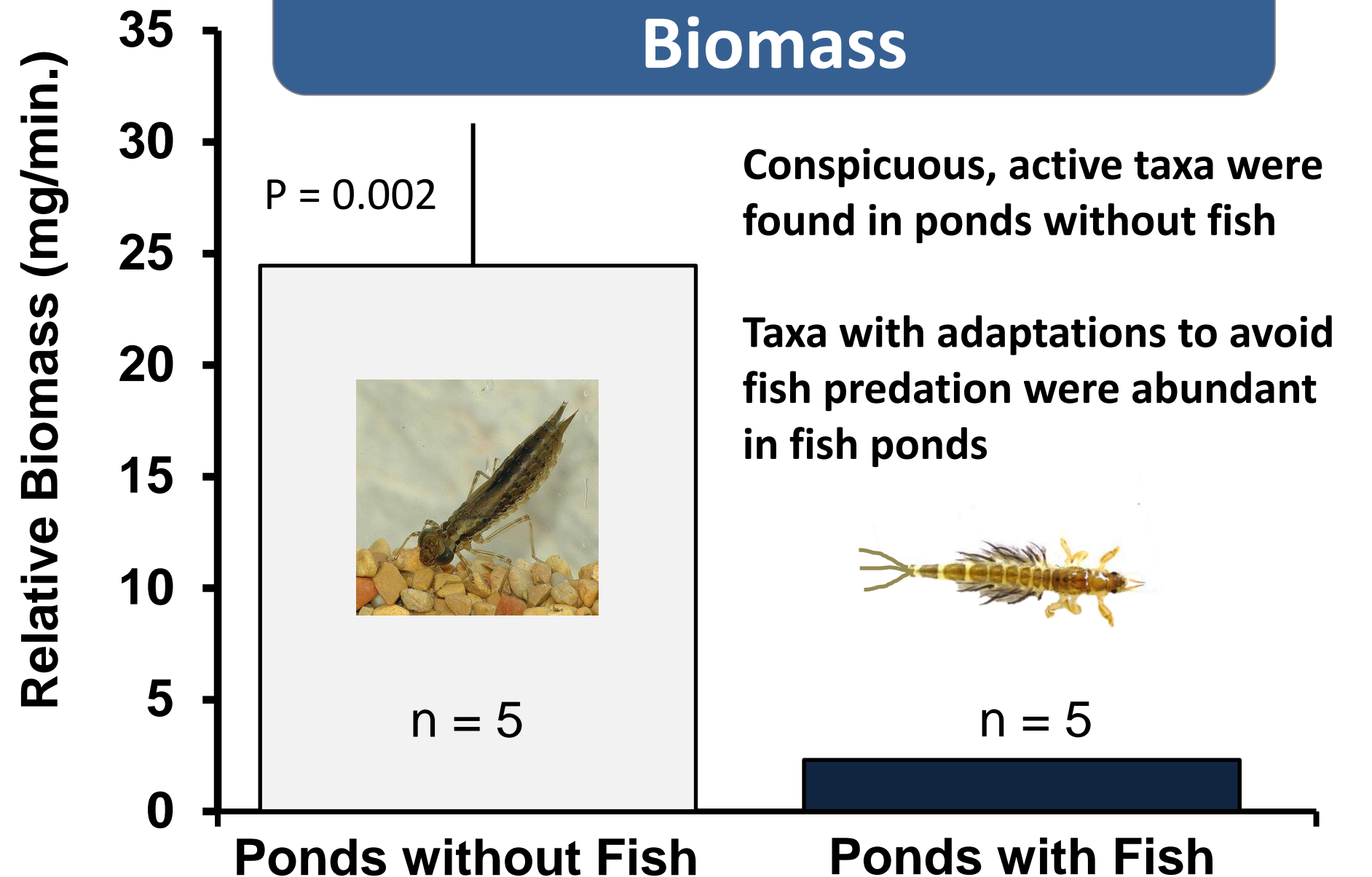


- Ten grassland ponds
  - Five ponds with fish
  - Five ponds without fish
- Determined CPUE biomass of macroinvertebrates
- Dried and analyzed invertebrates for total Hg



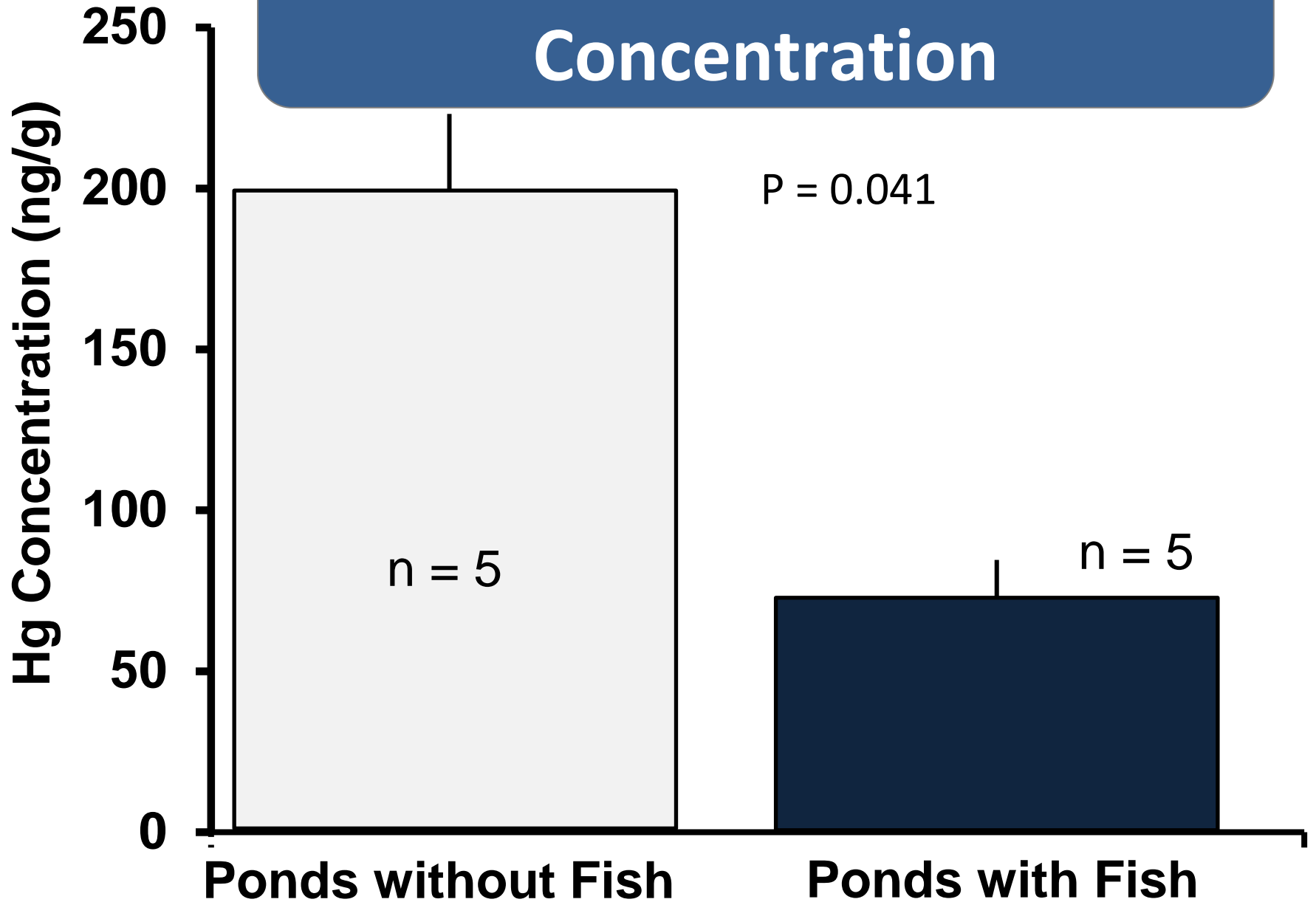
**DMA-80**

# Invertebrate Community Biomass

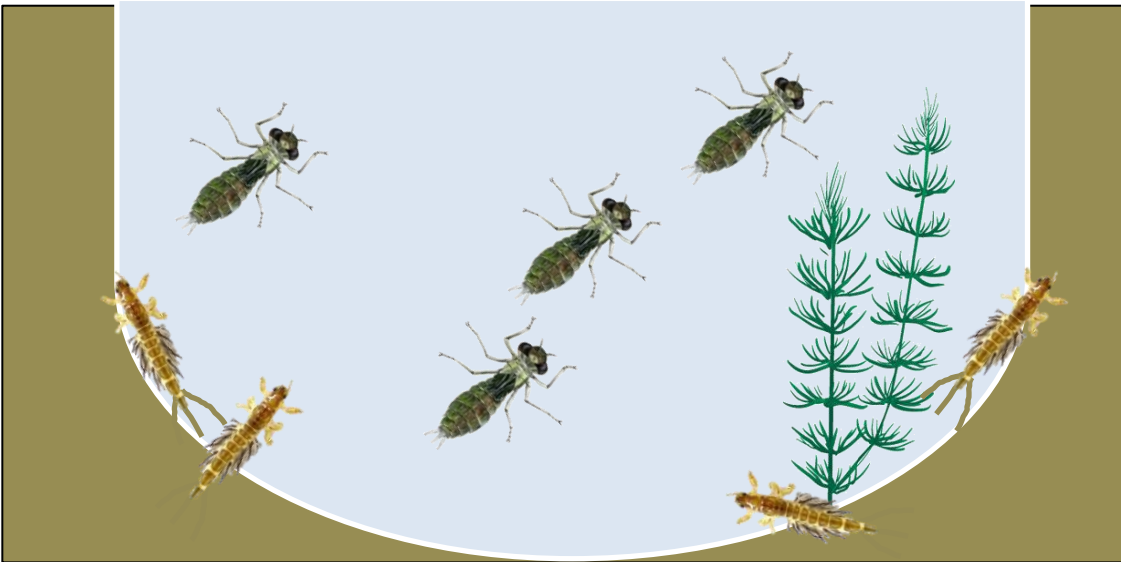




# Invertebrate Community Hg Concentration



**Hg Pool**



**Biomass (g)**

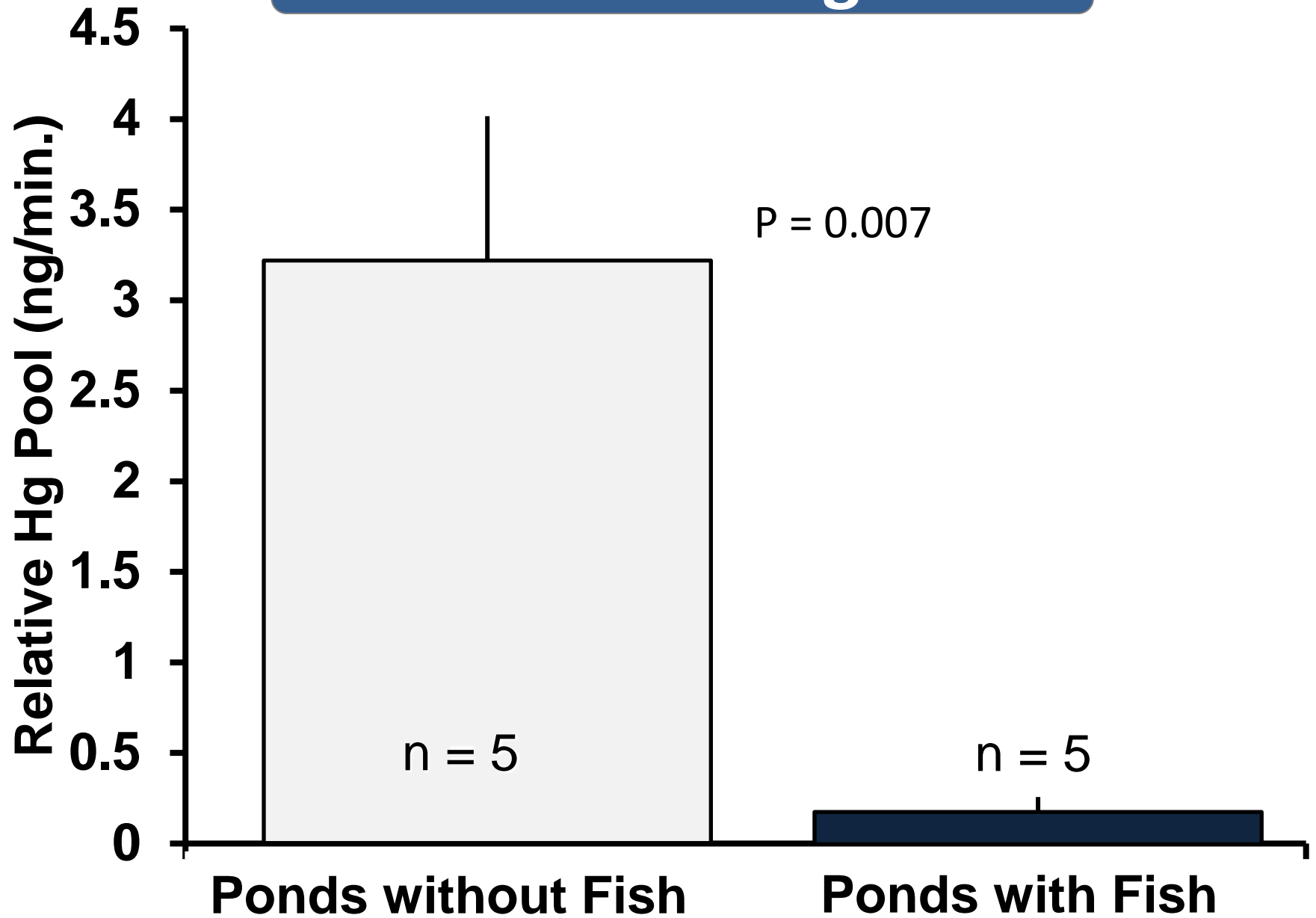
**X**

**Hg Conc.  
(ng/g)**

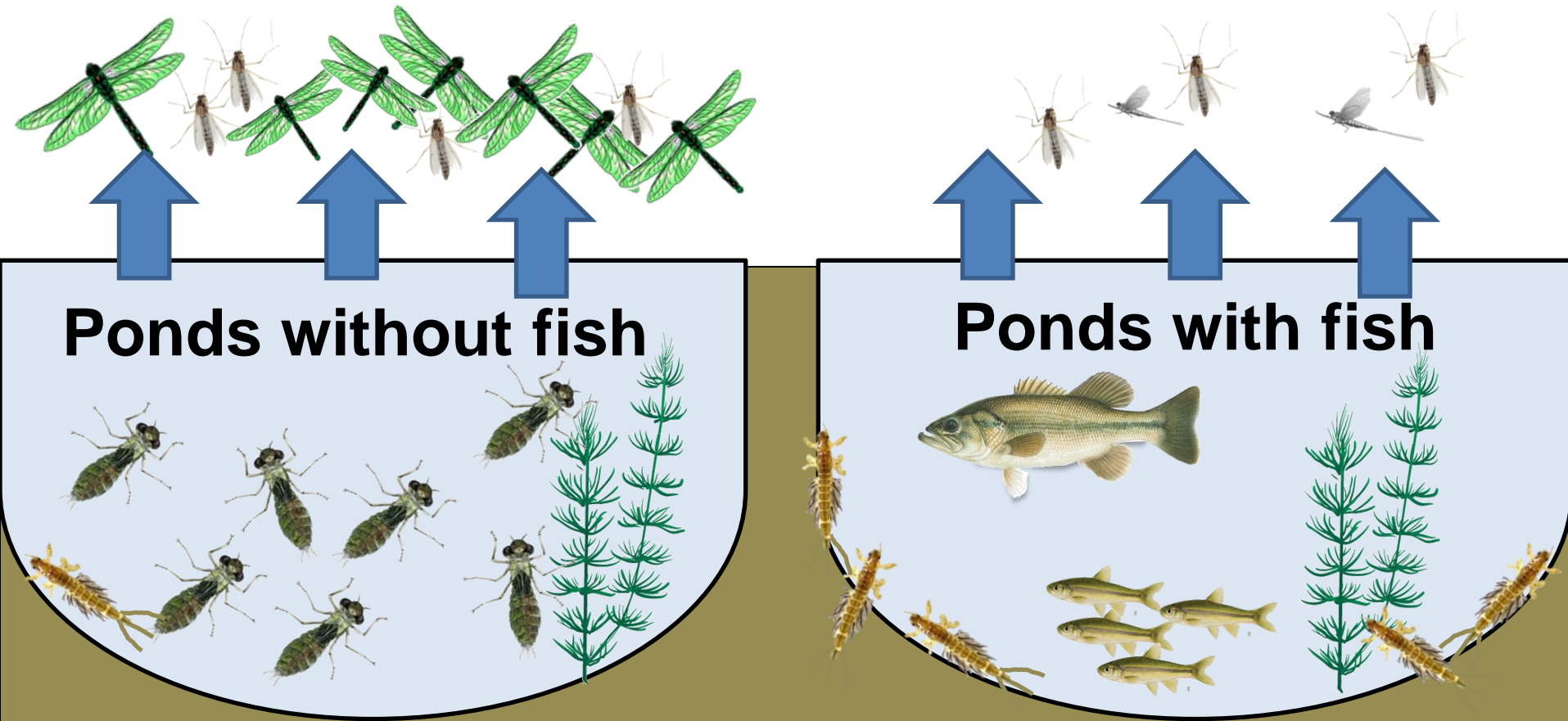
**=**

**Hg Pool (ng)**

# Invertebrate Hg Pool



# Hypothesized effect of fish





# Research Questions

1. Do fish affect Hg contamination of macroinvertebrate communities?
2. **Do fish affect insect-mediated MeHg flux from experimental ponds?**

# Study Site



**Experimental Pond Facility**

# Study Site

## Eagle Mountain Lake Hatchery



- Pond surface areas of 0.2-0.5ha, max depth 1m
- Contaminated with Hg from the atmosphere
- Ponds vary in Hg contamination



# Wildlife at the Pond Facility





# Experimental Design



Largemouth bass



Bluegill

- 5 Fish
- 5 Fishless
- Stocked 1 year before study with largemouth bass and bluegill

# Emergence Traps

**4 traps per pond**





# Emergence Traps

**Bottles collected and traps moved weekly**



**MeHg Flux**

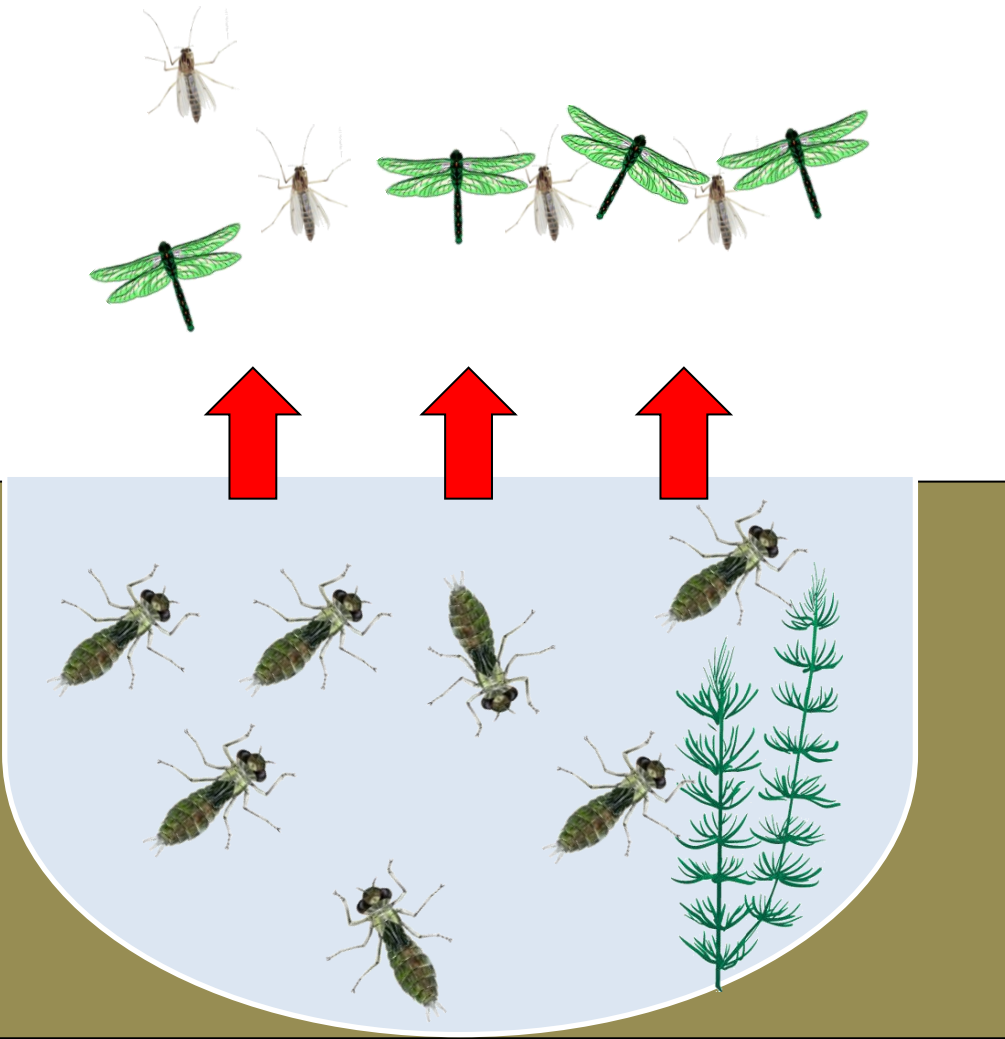
**Biomass (g)**

**X**

**MeHg Conc.  
(ng/g)**

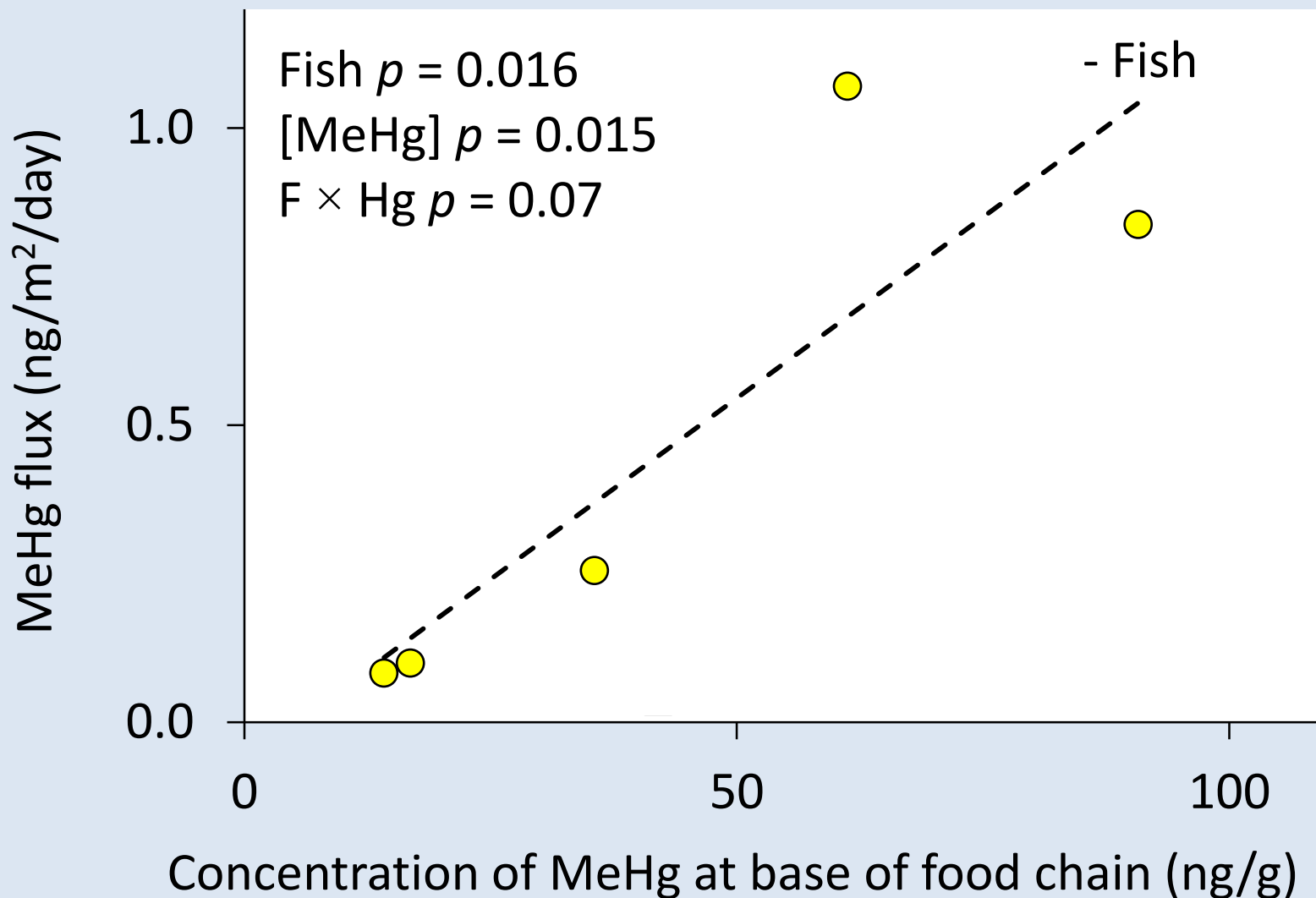
**=**

**MeHg Flux  
(ng)**

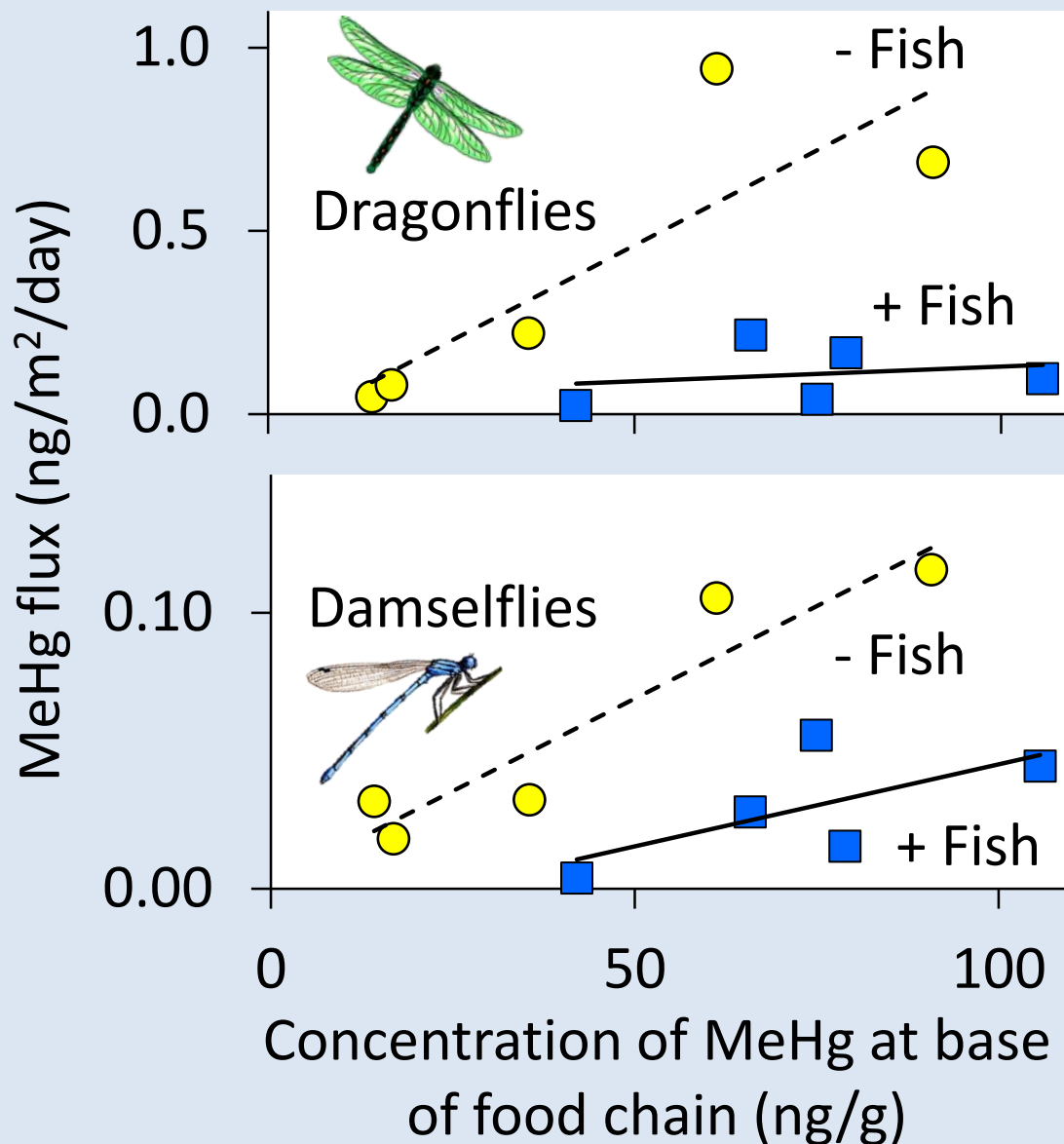




# Total Insect MeHg Flux



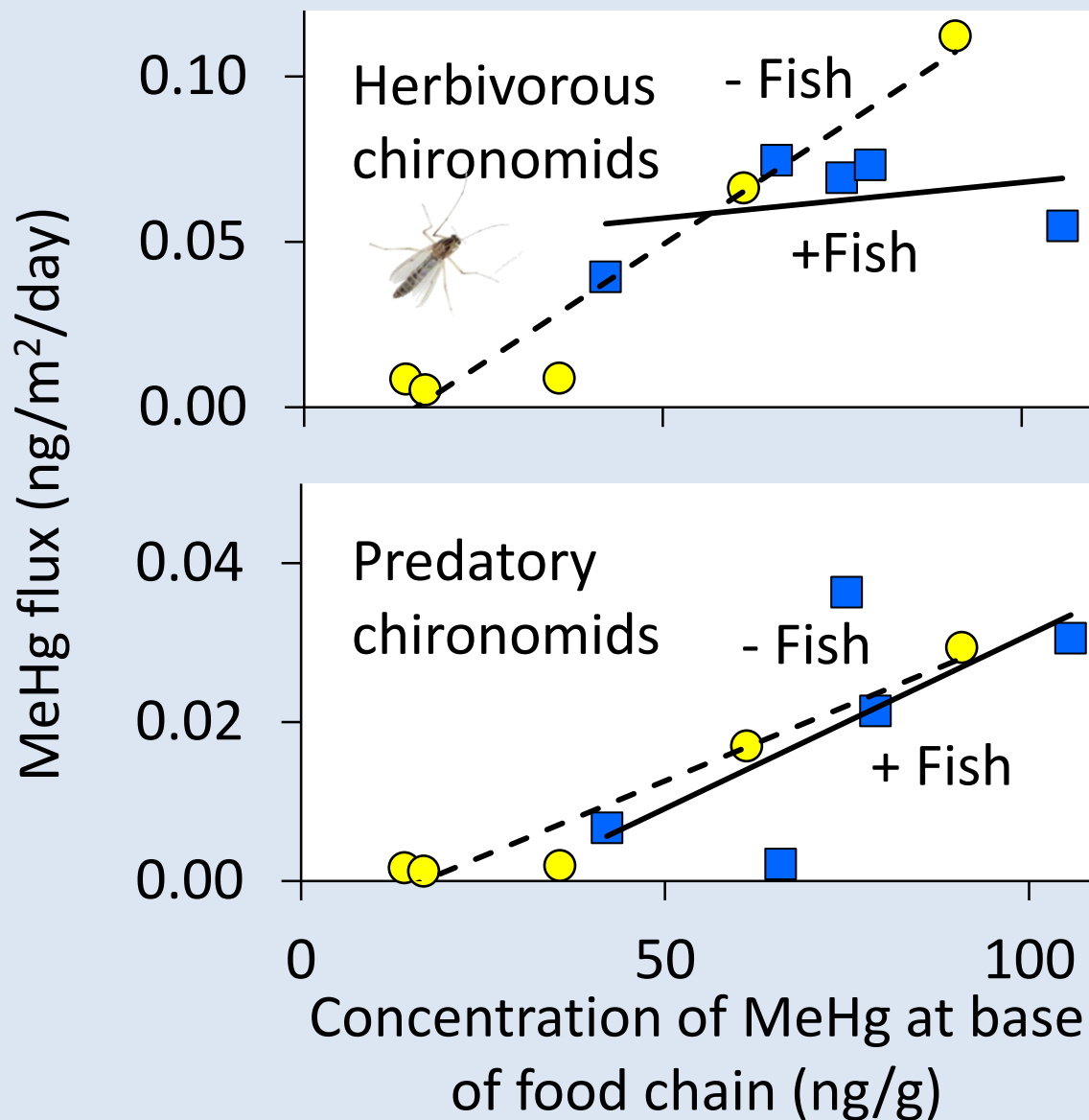
# “Large” insect Hg Flux



Fish  $p = 0.017$   
 [MeHg]  $p = 0.036$   
 $F \times \text{Hg } p = 0.10$

Fish  $p = 0.003$   
 [MeHg]  $p = 0.003$   
 $F \times \text{Hg } p = 0.18$

# "Small" insect Hg Flux



Fish  $p = 0.84$

[MeHg]  $p = 0.006$

$F \times \text{Hg}$   $p = 0.023$

Fish  $p = 0.68$

[MeHg]  $p = 0.008$

$F \times \text{Hg}$   $p = 0.82$

**Is MeHg flux in  
emergent insects  
correlated with Hg  
concentration in  
terrestrial consumers?**

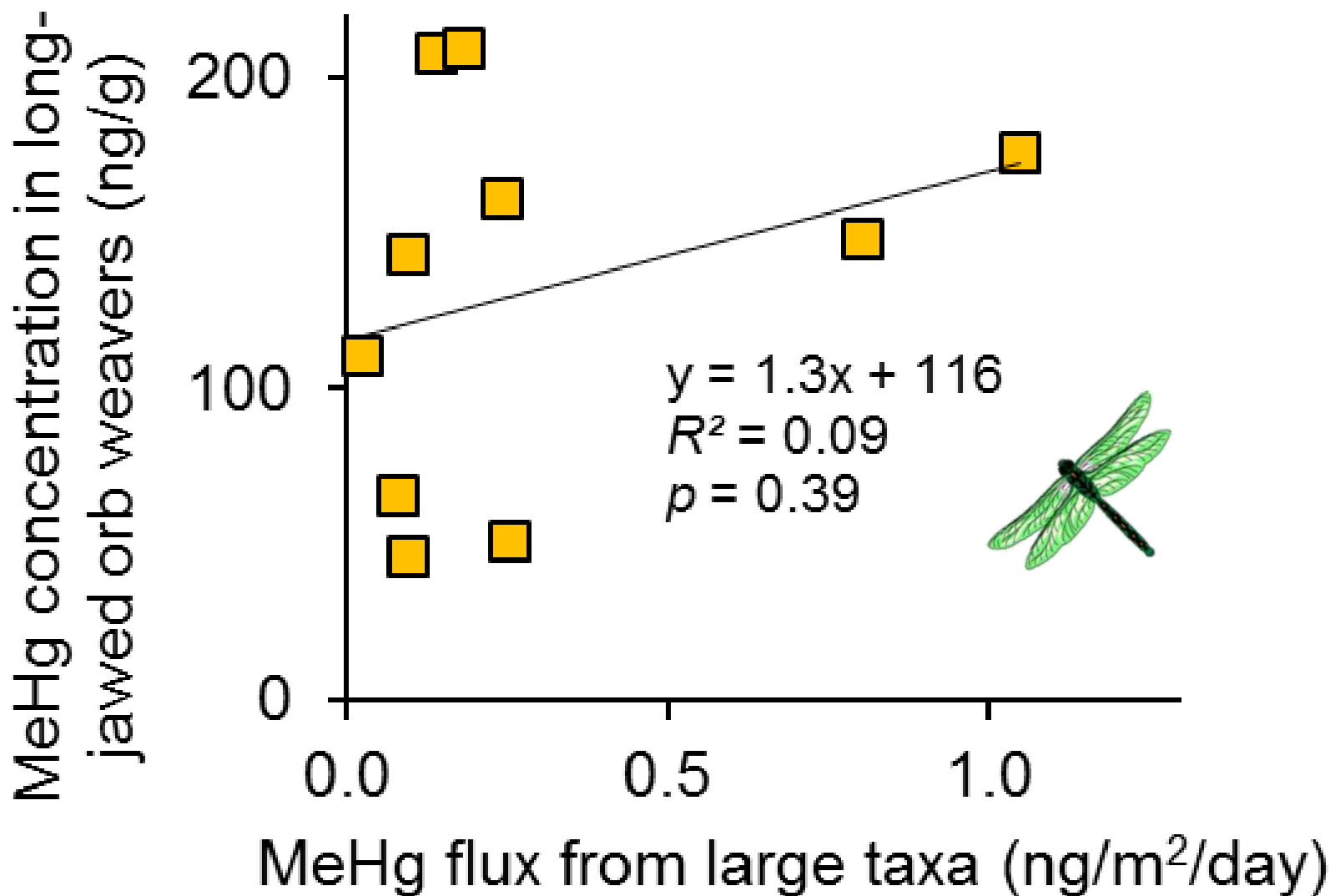


# Spider collection

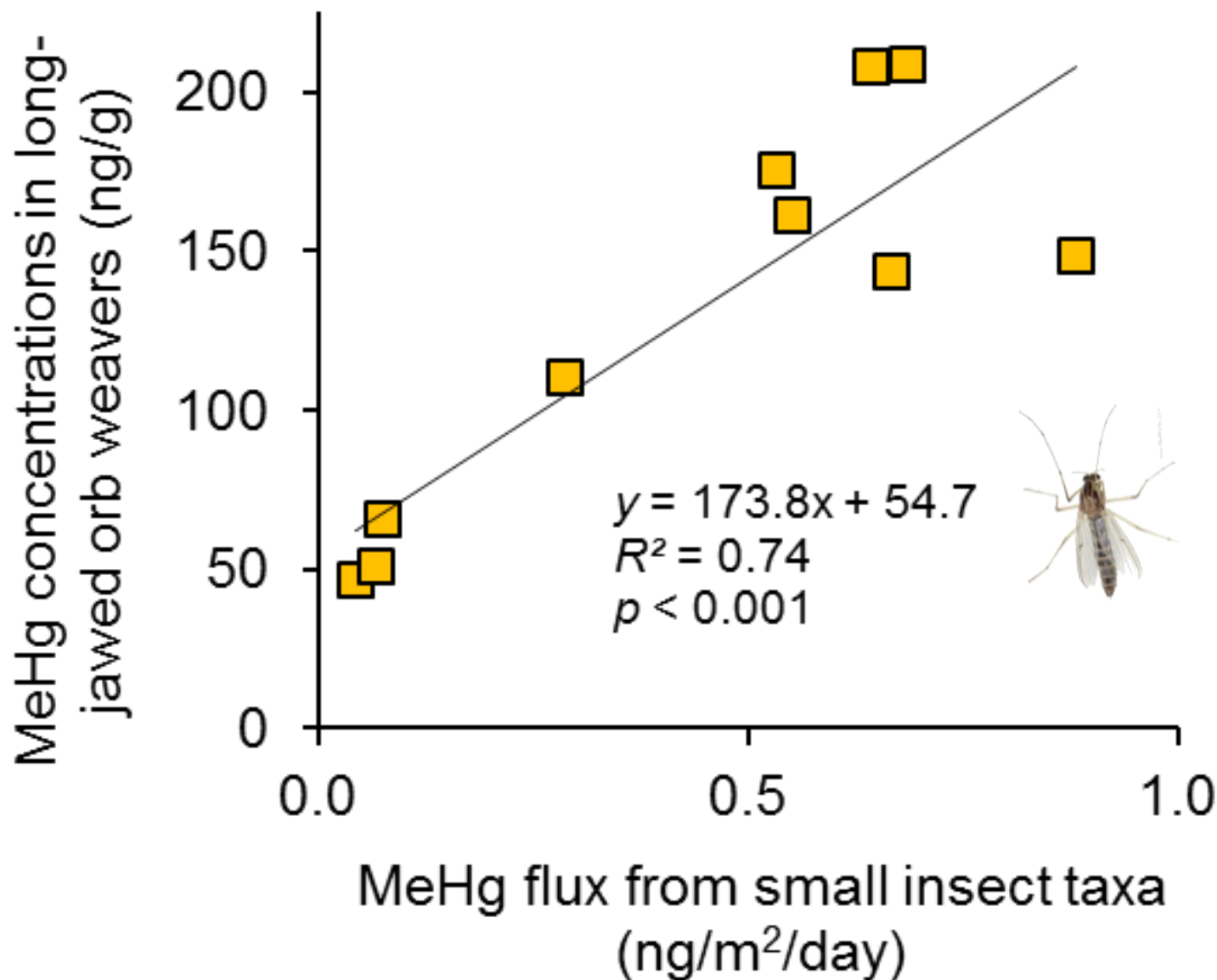
**Shoreline sweeps to collect spiders**



# MeHg Flux in “large” insects



# MeHg Flux in “small” insects







**Speir et al. 2013, Environ Toxicol and Chem**



**What is the potential  
impact of MeHg flux on  
terrestrial consumers?**

# Caddo Lake



0 2 km



Big Cypress Bayou

Dam

 Open water  
 Forested wetland

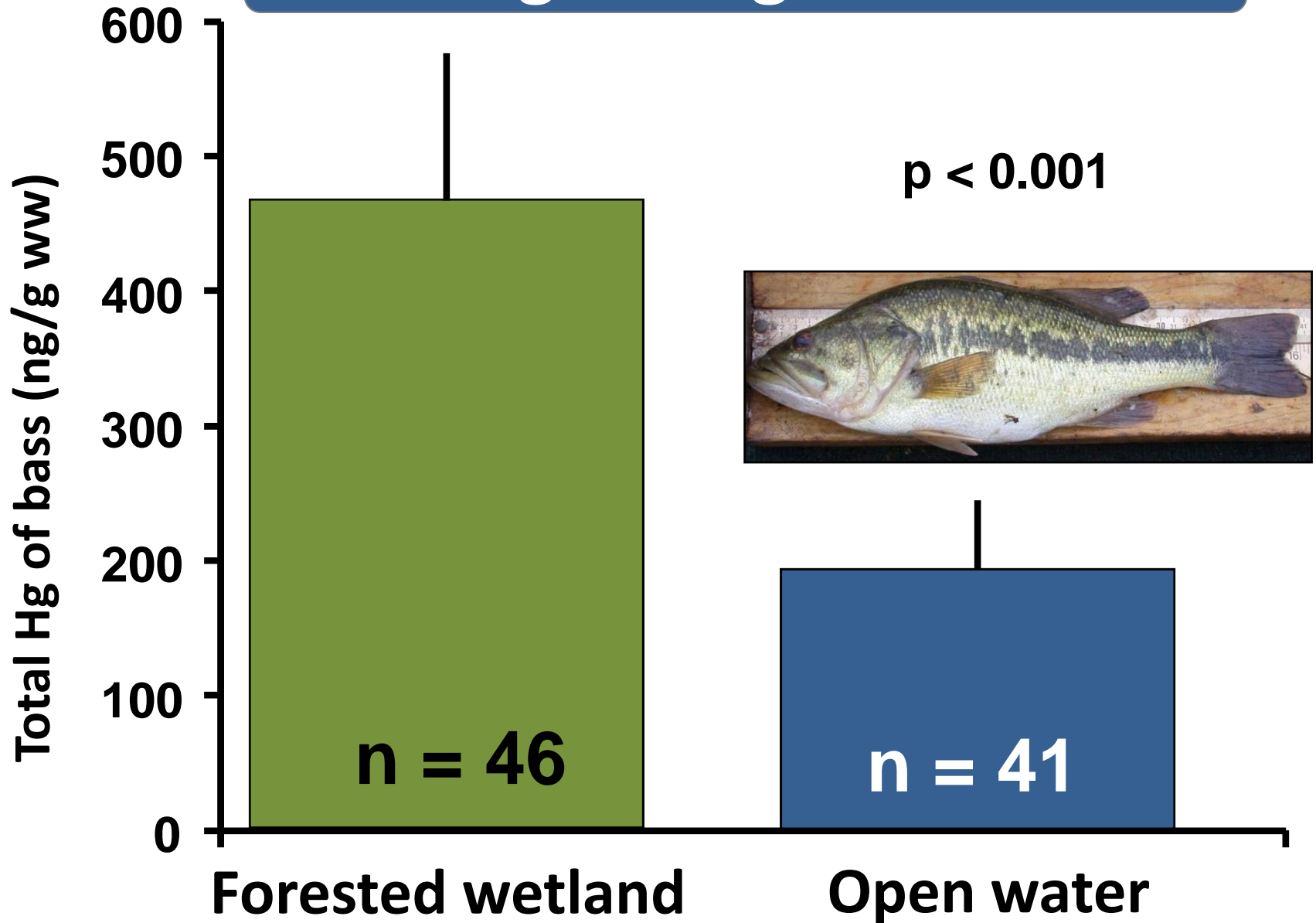


32°41'—

93°59'

Texas Louisiana |

# Total Hg in Largemouth bass



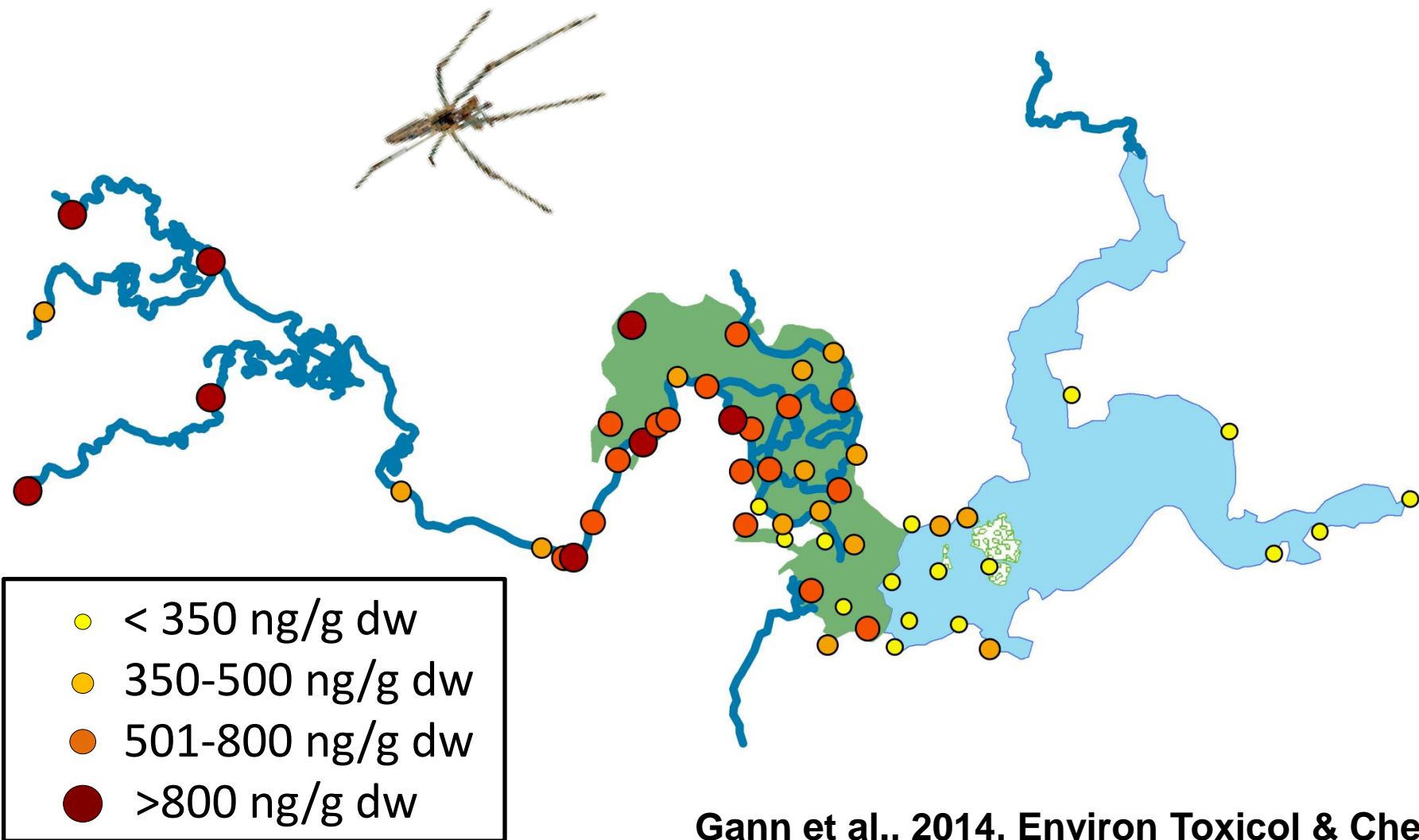
# Spider Sampling



- 56 sampling sites
- 10 spider minimum per site





# Total Hg Concentrations in Spiders



Gann et al., 2014, Environ Toxicol & Chem



# Risk to Bluebirds

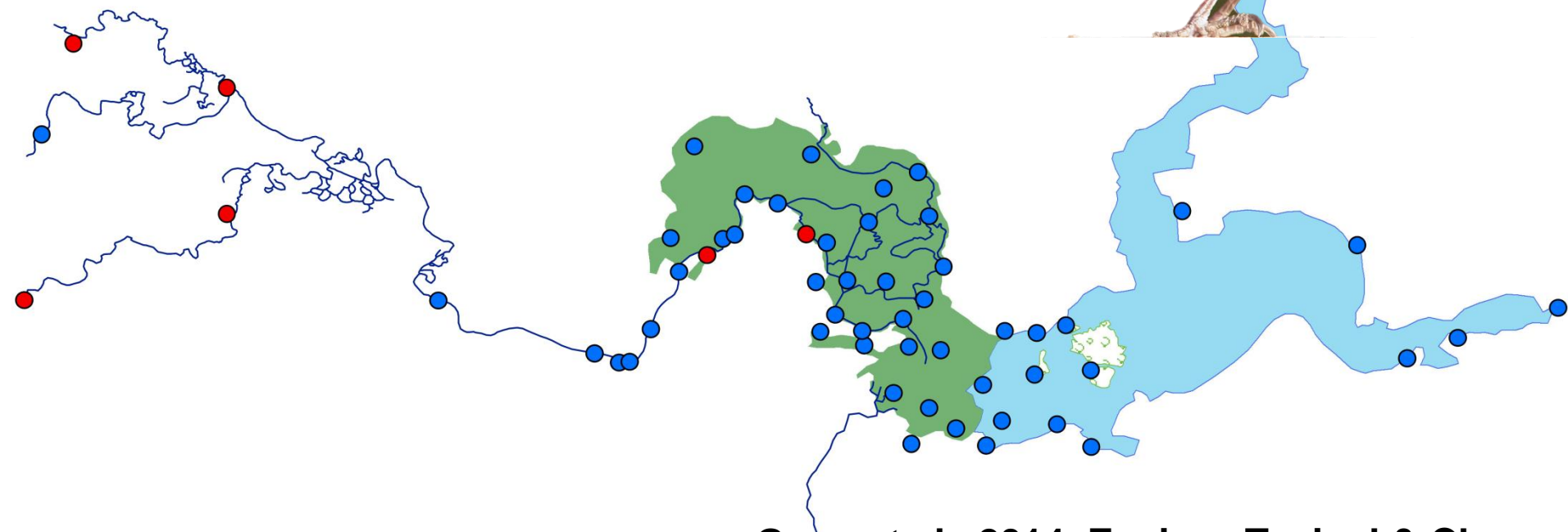
-  Spiders below toxicity threshold
-  Spiders above toxicity threshold



Gann et al., 2014, Environ Toxicol & Chem



# Risk to Wrens

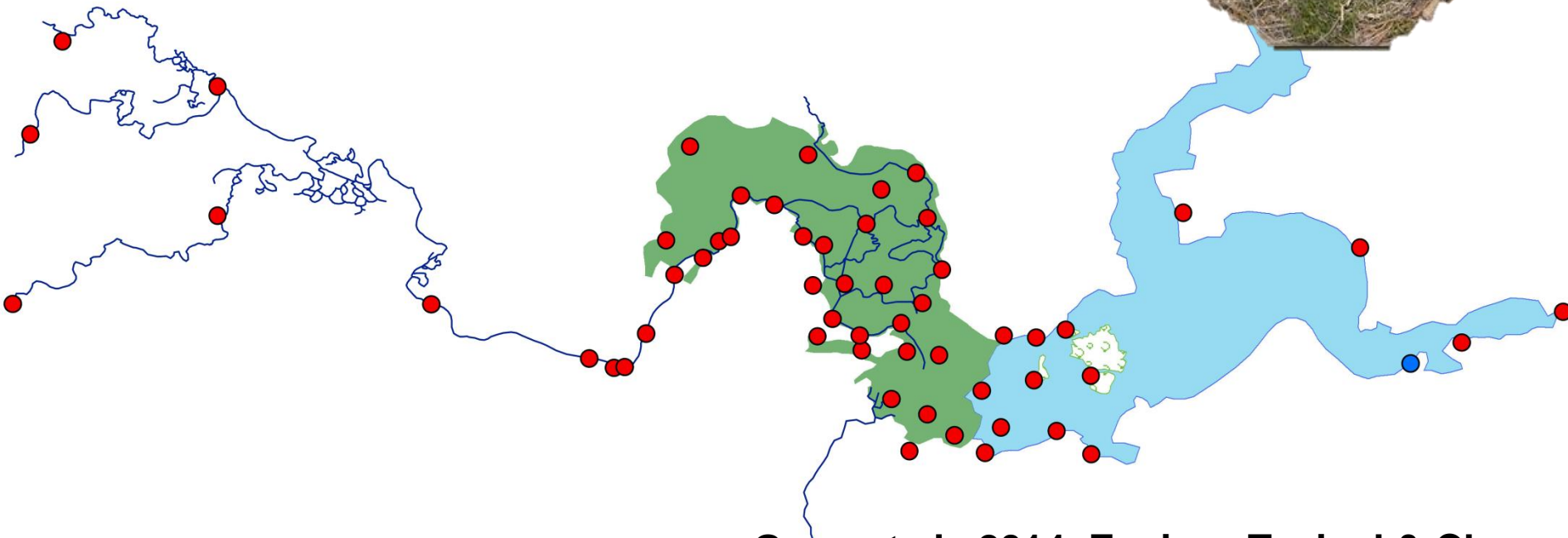
-  Spiders below toxicity threshold
-  Spiders above toxicity threshold



Gann et al., 2014, Environ Toxicol & Chem

# Risk to Nestling Chickadees

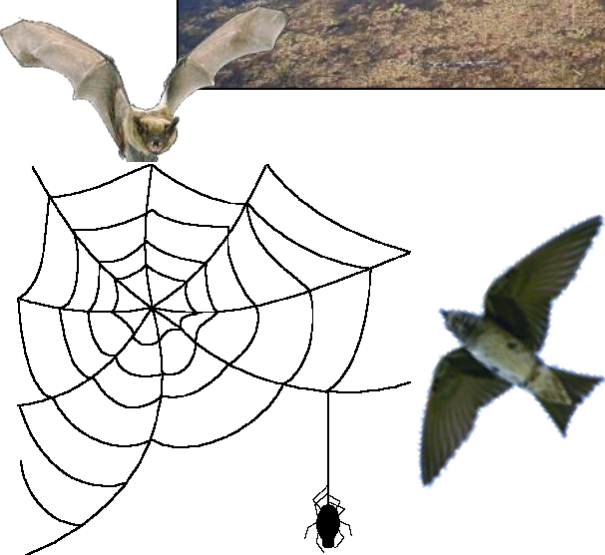
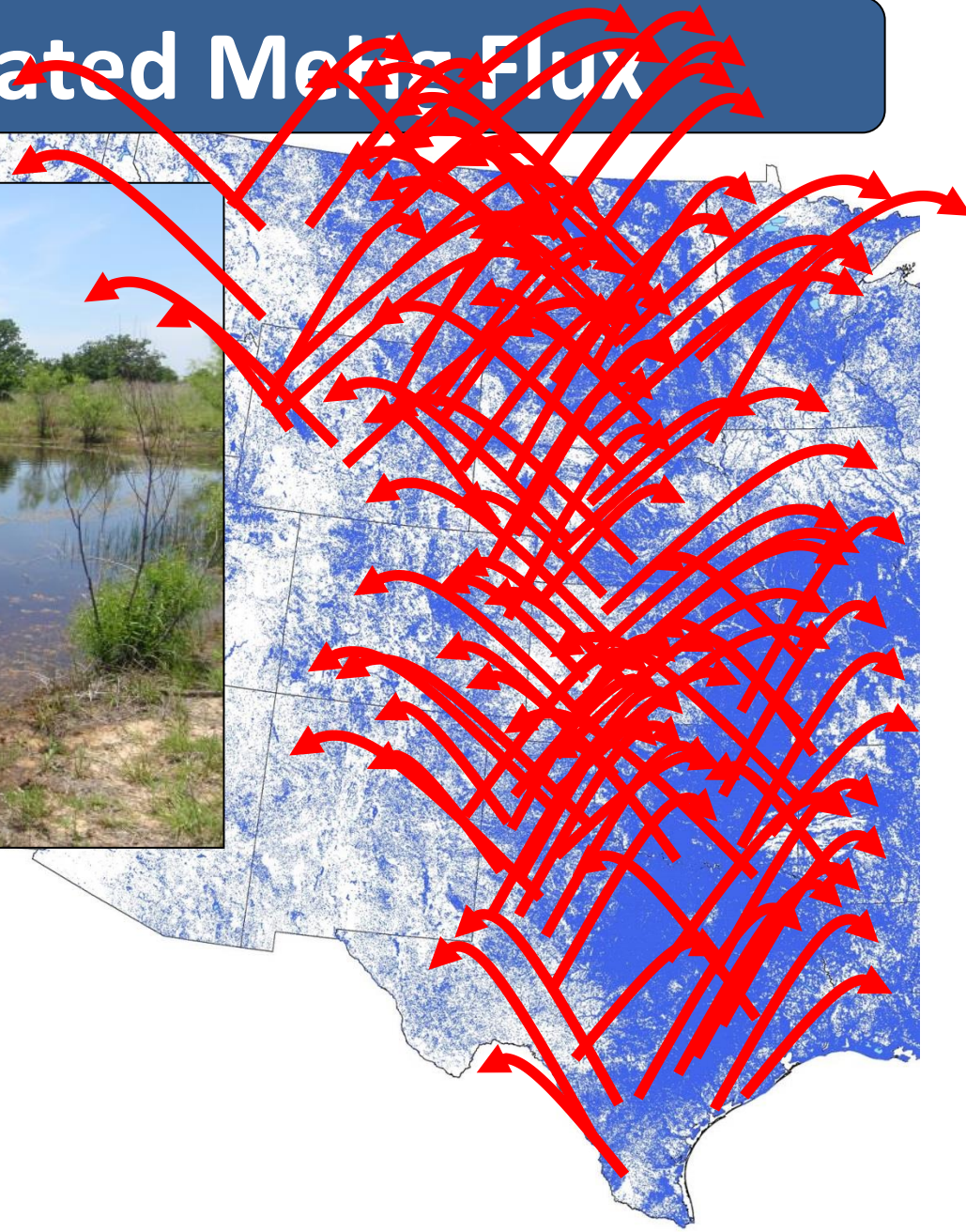
-  Spiders below toxicity threshold
-  Spiders above toxicity threshold



Gann et al., 2014, Environ Toxicol & Chem

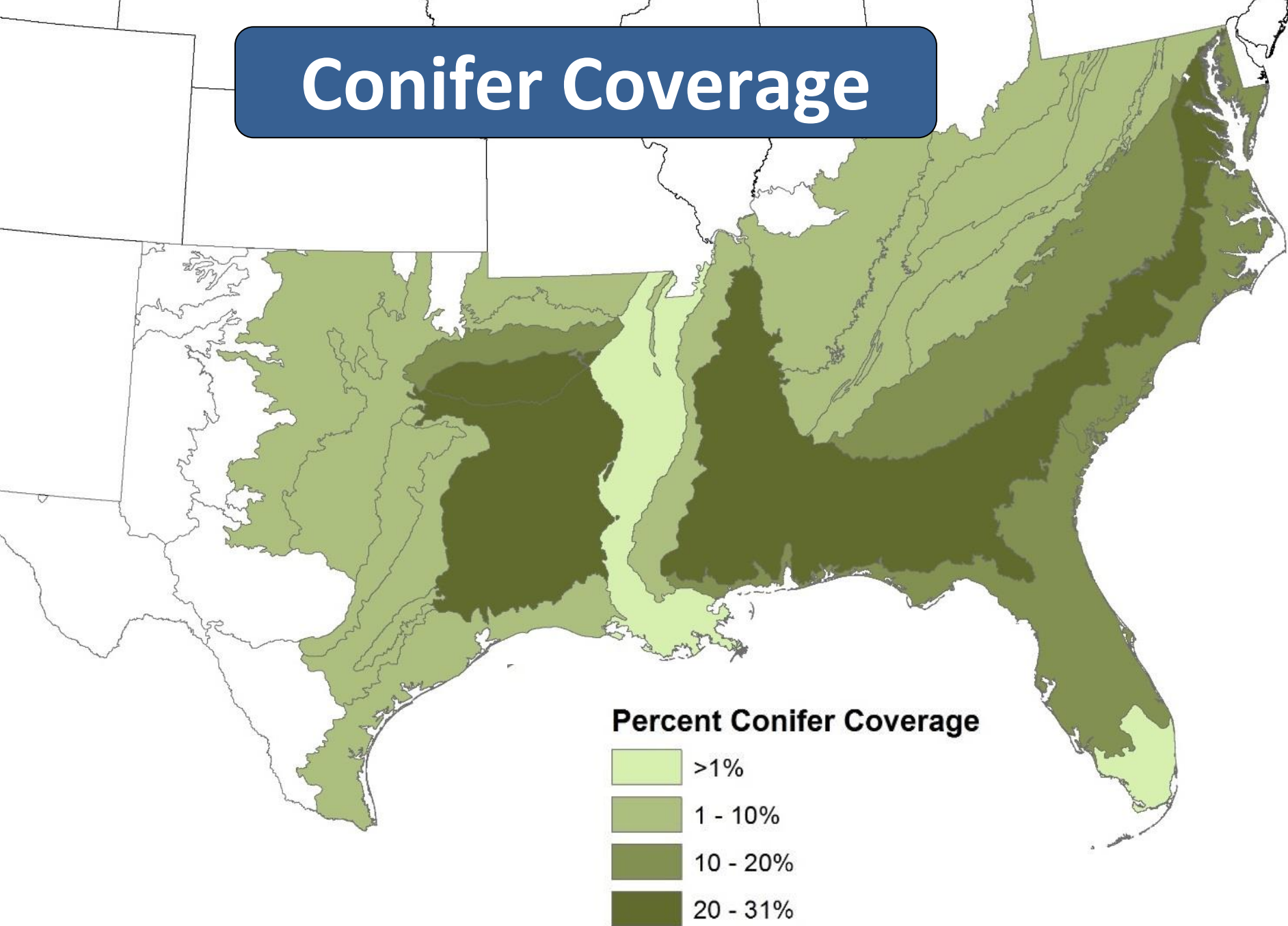


# Insect-Mediated Melting Flux



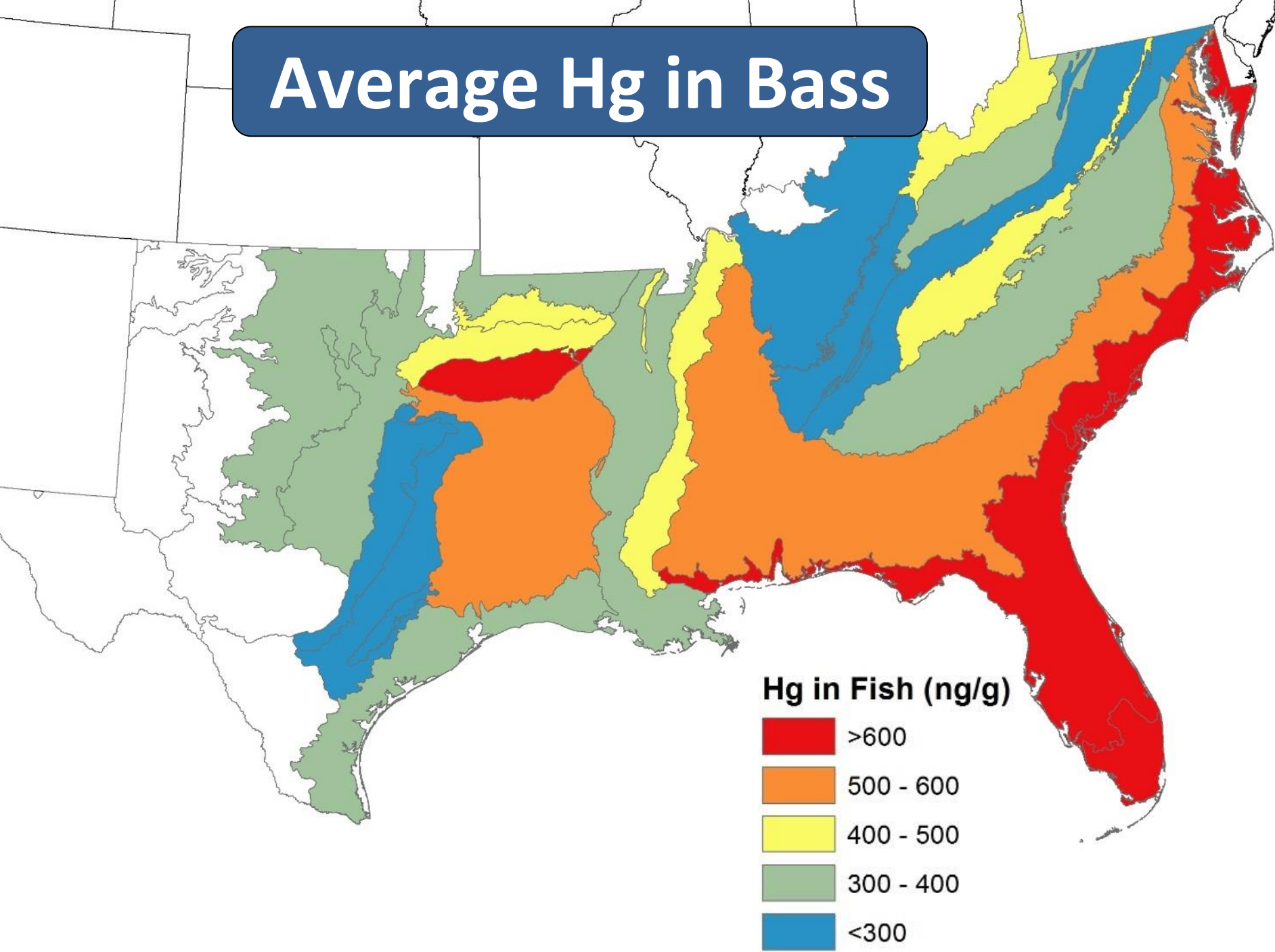
# **Future Research**

# Conifer Coverage





# Average Hg in Bass





# Waterbodies

A map of the United States where water bodies are highlighted in blue. The map shows the outlines of the states and the surrounding oceans. The blue areas represent lakes, rivers, and other water features across the country.

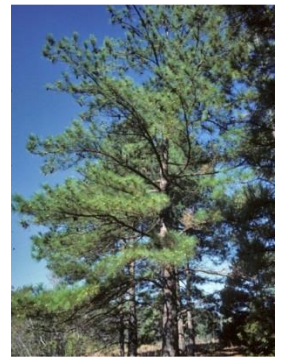
- 3,380,209 waterbodies in the south
- 2,642,705 in ecoregions with Hg >300 ng/g



# Implications of Research



# Mercury contamination in the south central US: Patterns, causes and consequences



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